REMEDIAL ALTERNATIVES TECHNOLOGY SCREENING
PATRICK BAYOU SUPERFUND SITE
DEER PARK, TEXAS

Prepared for

Patrick Bayou Joint Defense Group

U.S. Environmental Protection Agency

Prepared by

Anchor QEA, LLC

614 Magnolia Avenue

Ocean Springs, Mississippi 39564

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LIST OF ACRONYMS AND ABBREVIATIONS

AB	Artificial Banks
AC	activated carbon
ACBM	Articulated Concrete Block Mat
AOC	Administrative Settlement Agreement and Administrative Order on Consent
ARAR	Applicable and Relevant or Appropriate Requirement
ATSDR	Agency for Toxic Substances and Disease Registry
BEHP	bis(2-ethylhexyl) phthalate
BERA	Baseline Ecological Risk Assessment
bgs	below ground surface
BHHRA	Baseline Human Health Risk Assessment
BMP	Best Management Practice
CAD	confined aquatic disposal
CDF	confined disposal facility
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulation
cm	centimeters
COC	chemical of concern
COPC	chemical of potential concern
CSM	conceptual site model
cy	cubic yard
DCA	Decision Consequence Analysis
DQO	Data Quality Objective
EF	East Fork
EMNR	Enhanced Monitored Natural Recovery
FS	Feasibility Study
GBA	Gahagan and Bryant Associates, Inc.
GRA	General Response Action
HSC	Houston Ship Channel
IC	indicator chemical
JDG	Patrick Bayou Joint Defense Group
Lubrizol	The Lubrizol Corporation

MCA	Marine Conservation Agreement
mg/kg	milligrams/kilogram
MNR	Monitored Natural Recovery
NAVD 88	North American Vertical Datum 1988
NCP	National Contingency Plan
NCR	National Research Council
NE	Net Erosional
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NS	Nearshore
NSR	net sedimentation rate
OMM	operations, monitoring, and maintenance
OW	Open-Water
OxyVinyls	OxyVinyls, LP
PAH	polycyclic aromatic hydrocarbon
PB	Patrick Bayou
PCB	polychlorinated biphenyl
POHA	Port of Houston Authority
POTW	publically owned treatment works
ppt	parts per thousand
PRAO	Preliminary Remedial Action Objective
PRG	preliminary remediation goal
PSCR	Preliminary Site Characterization Report
psf	pounds per square foot
RAL	Remedial Action Level
RAO	Remedial Action Objective
RI/FS	Remedial Investigation/Feasibility Study
S/S	solidification/stabilization
SH	State Highway
Shell	Shell Chemical/Oil
Site	Patrick Bayou Superfund Site
SMA	sediment management area
ST	Structures

TBC	to be considered
TCEQ	Texas Commission on Environmental Quality
TDH	Texas Department of Health
TEQ	Toxic Equivalent
TPWD	Texas Parks and Wildlife Department
TRRP	Texas Risk Reduction Program
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
VCP	Voluntary Cleanup Program
VST	vane shear test
WWTP	wastewater treatment plant

EXECUTIVE SUMMARY

This *Remedial Alternatives Technology Screening* document describes the preliminary screening of potential remedial technologies for the Patrick Bayou Superfund Site (Site). The screening of remedial technologies is the first stage in the development of remedial alternatives for the Site. The remedial technologies retained for further evaluation in this document will be incorporated into the remedial alternatives that will be developed and evaluated in a *Feasibility Study* (FS) for the Site. The screening of remedial technologies was performed using the criteria for the screening of remedial alternatives in the National Contingency Plan—*Code of Federal Regulations* (CFR), Title 40, Part 300.430(e)(7)—and in accordance with the *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (USEPA 1988), *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study* (USEPA and USACE 2000), and related guidance documents. The development and screening of remedial alternatives for the Site is part of the FS, identified as Task 6 in the Administrative Settlement Agreement and Administrative Order on Consent (AOC) for the Patrick Bayou Superfund Site.

This *Remedial Alternatives Technology Screening* includes a description of the physical conditions and the remedial action objectives for the Site, which forms the basis for the evaluation of remedial technologies. The technologies evaluated in the screening include a wide range of General Response Actions (GRA), including institutional controls, monitored natural recovery, in-situ containment, in-situ treatment, removal, ex-situ treatment, and disposal. The purpose of this document is to explore potentially applicable remedial technologies to enhance the ecological condition of the Site given these, and other, factors. Results from the *Baseline Ecological (BERA) and Human Health Risk Assessments (BHHRA)* have been incorporated into this technology review and will be considered in the FS to support the selection of an appropriate remedy to address potential ecological risks.

Note that public access to the Site for recreational activity (e.g., fishing, swimming) is restricted by physical barriers/controls and institutional controls (e.g., plant security). Thus, direct exposure of the general public to Site contaminants is not considered a reasonably complete scenario. Although contaminated fish and shellfish may migrate off-Site and be caught and consumed by the public, the *Baseline Human Health Risk Assessment* (Anchor QEA 2012) performed for the Site concluded that there is no observable incremental contribution from the Site to the concentration of contaminants in the tissue of fish in the Houston Ship Channel (HSC). An additional consideration in the development and evaluation of remedial alternatives is that the City of Deer Park has initiated a major project to construct a detention basin that may reduce the erosional forces of high-flow events and enhance natural recovery.

Appendix A of this document is a preliminary screening of treatment technologies reviewed for consideration in the development of remedial alternatives. A broad range of remedial treatment technologies was evaluated as described in the appendix. Certain technologies were retained as potentially applicable to the Site to be carried into the development of remedial alternatives while other treatment technologies were assessed as inapplicable to the Site for reasons described in the appendix.

The potential remedial technologies retained for consideration in the FS are summarized in Table ES-1. In the event that sediment or other material must be removed from the Site as part of the remedial action, ex-situ treatment and disposal technologies would also need to be considered in the FS. Table ES-2 presents a summary of retained ex-situ treatment and disposal technologies.

Table ES-1

Remedial Technology Screening Summary

General Response Action	Technology Type	Process Option
Institutional Controls	Administrative and Legal Controls	Access and property use restrictions
		Informational devices (e.g., signage and fish consumption advisories)
Natural Recovery	Monitored Natural Recovery	Sedimentation
		Placement of thin layer of clean cover
In-situ Containment	Capping	Articulated Concrete Block Mat (ACBM)
		Aggregate and Natural Materials
In-situ Treatment	Physical-Immobilization	Adsorptive Amendments
Removal[1]	Dry Excavation	Soil Excavators
	Dredging	Mechanical Dredging
		Hydraulic Dredging

Notes:
1. Sediment removal is potentially applicable in conjunction with other remedial technologies, such as in-situ containment, to maintain hydraulic capacity in constrained portions of the channel.

Table ES-2

Ex-Situ Treatment and Disposal Technology Screening Summary[1]

General Response Action	Technology Type	Process Option
Ex-situ Treatment	Immobilization	Solidification/Stabilization (S/S)
	Thermal	Incineration
Aquatic Disposal	Confined Aquatic Disposal	N/A
	Nearshore Confined Disposal	N/A
Upland Disposal	Landfill	N/A

Notes:
1. Ex-situ treatment and disposal technologies are considered for management of sediment that may be removed from the Site.
N/A – Not applicable

1 INTRODUCTION

This *Remedial Alternatives Technology Screening* was prepared as part of a *Remedial Investigation/Feasibility Study* (RI/FS) for the Patrick Bayou Superfund Site (Site), Deer Park, Texas (Figure 1-1). The document develops and screens a range of preliminary remedial technologies that could be implemented at the Site in relation to the Remedial Action Objectives (RAOs). Results of these evaluations will be carried forward for further consideration in the Site *Feasibility Study* (FS). It should be noted that the *Baseline Ecological Risk Assessment* (BERA; Anchor QEA 2013) is being submitted concurrently with this *Remedial Alternatives Technology Screening* and the final *Baseline Human Health Risk Assessment* (BHHRA; Anchor QEA 2012b) for the Site has been submitted. The results of these assessments will play an important role in determining the final range of remedial alternatives that will be considered in the FS.

1.1 Background and Regulatory Framework

On September 5, 2002, the U.S. Environmental Protection Agency (USEPA) listed the Site on the National Priorities List (NPL) under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), also known as Superfund. The RI/FS is being performed by the Respondents for the Site, collectively referred to as the Patrick Bayou Joint Defense Group (JDG), which entered into an Administrative Settlement Agreement and an Administrative Order on Consent (AOC) with the USEPA, Region 6, on January 31, 2006. The JDG members include OxyVinyls, LP (OxyVinyls), Shell Chemical/Oil (Shell), and The Lubrizol Corporation (Lubrizol). This document was prepared to address the requirements outlined in Task 6: Development and Screening of Alternatives in the Statement of Work of the AOC for the RI/FS. The RI/FS will be used to identify the preferred alternative and ultimately lead to a proposed plan for the Site.

1.2 Objectives of the Remedial Alternatives Technology Screening Document

The objectives of the *Remedial Alternatives Technology Screening* document are to:

- Reiterate the Preliminary Remedial Action Objectives (PRAOs) for the Site. PRAOs were developed in the *Preliminary Site Characterization Report* (PSCR; Anchor 2006) and they are summarized again in this document.

- Identify and screen remedial technologies (such as monitored natural recovery, sediment containment, sediment removal, or sediment disposal/treatment) to eliminate candidate remedial technologies that cannot be implemented or that may be limited in their applicability due to technical, cost-benefit considerations, or other constraints at the Site.
- Identify and screen potential disposal alternatives for removed contaminated sediment, and eliminate disposal process options that are not practical to implement.
- Identify the preliminary Applicable or Relevant and Appropriate Requirements (ARARs) for the protection of human health or the environment at the Site.

The PRAOs for the Site, developed in the PSCR, are narrative statements that are medium- or area-specific goals for protecting the environment (USEPA 1988). The PRAOs address the primary exposure pathways, receptors, and risk drivers, based on the current understanding of the Site. The PRAOs also describe in general terms what the sediment cleanup will accomplish for the Site, help focus the development of remedial alternatives, and form the basis for establishing preliminary remediation goals (PRGs).

The purpose of screening remedial technologies, screening disposal sites, and developing PRAOs is to efficiently eliminate remedial technologies, disposal options, and alternatives that are not practicable, so the FS can fully develop and focus on viable remedial alternatives. Site-specific conditions may limit the remedial alternatives that are feasible, and this preliminary evaluation will factor Site-specific conditions into the evaluation of potential remedial alternatives and disposal sites. This approach is consistent with USEPA RI/FS guidance (USEPA 1988) and contaminated sediment remediation guidance (USEPA 2005).

After completion of the preliminary screening of technologies in this report, a detailed evaluation of the retained technologies and an assembly of remedial alternatives will occur as part of the FS. The FS will develop potential remedial alternatives, analyze the alternatives against CERCLA evaluation criteria, and compare the alternatives against one another.

1.3 Remedial Alternatives Technology Screening Assumptions

The following assumptions apply to the preliminary screening and summary of remedial technologies for the Site:

- Polychlorinated biphenyls (PCBs) are identified as the primary indicator chemical (IC) for the Site (Section 2.3); the primary exposure pathway associated with this IC group is direct or indirect contact with sediments and surface water within the Site boundary established by the USEPA in the AOC. This IC is the primary chemical of potential concern (COPC) evaluated in the BERA that resulted in risks to receptors above an acceptable threshold (i.e., hazard quotient exceeding unity) for aquatic dependent wildlife. The BERA also identified polycyclic aromatic hydrocarbons (PAHs), lead and bis(2-ethylhexyl) phthalate (BEHP) as potential contributors to sediment toxicity; however, PCBs were the primary COPC for benthic receptors. The BHHRA did not identify unacceptable risk for any COPC. In addition, other COPCs are generally colocated with PCBs at the Site and reducing the concentrations of the IC will also mitigate concentrations and risk from other COPCs. For these reasons, PCBs are the chemicals most relevant to the preliminary screening of remedial technologies and are, therefore, the focus of this document.
- The preliminary screening relies on the current understanding of physical conditions that affect sediment stability and the distribution of surface and subsurface sediment contamination. The dataset, upon which this understanding is based, has been submitted to the USEPA and is identified and described in the PSCR (Anchor 2006); *Work Package 2 Work Plan, Hydrodynamic Field Data Collection and Contaminant Source Evaluation* (Anchor 2007a); *Sediment and Surface Water Contaminant of Potential Concern Delineation Report* (Anchor QEA 2010); and *Upstream Patrick Bayou Characterization Data Report* (Anchor QEA 2012a).
- Cleanup levels for the IC group compounds, remedial action levels (RALs), and sediment management areas (SMAs), if warranted and/or applicable, have not yet been defined. PCBs are the primary chemicals of concern (COCs) based on risks to aquatic dependent wildlife and benthos (Anchor QEA 2013). Although PRAOs are described in this document, and a framework for defining SMAs is proposed, RAOs, RALs, and SMAs will be refined and finalized in the FS report.

The assumptions identified above are necessary to perform the screening described in this document. Because the remedial footprint has not yet been determined, not all technologies screened in this document likely will be considered in the FS. Moreover, as the technologies screened in this document represent a full-range of available technologies, it is not anticipated that additional technologies beyond those retained in this document will need to be considered in the FS.

1.4 Document Organization

The remainder of this *Remedial Alternatives Technology Screening* document includes the following major sections:

- Section 2 – Basis for the Evaluation – This section describes the Site characteristics and conceptual site model (CSM) that form the basis of the evaluation for screening remedial alternatives.
- Section 3 – Basis for Remedial Action – This section presents PRAOs, and describes the basis for remedial action, including a proposal for the development of RALs and identification of ARARs.
- Section 4 – Identification and Screening of Remedial and Disposal Technologies – This section identifies and screens remedial and disposal technologies.
- Section 5 – Technology Summary – This section summarizes technology constraints applicable for each SMA and outlines the conclusions of the remedial alternatives technology screening.
- Appendix A – Treatment Technology Review – This appendix contains the Treatment Technology Review.
- Appendix B – Proposed Detention Basin Plans – This appendix contains information about the location and plans for the construction of the detention basin proposed by the City of Deer Park.
- Appendix C – Response to Comments.

2 BASIS FOR THE EVALUATION

2.1 Physical Site Characteristics

Physical characteristics of the Site that are important in considering appropriate remedial approaches to managing potential sediment impacts at the Site include the size of the Site, the presence of facilities surrounding the waterway and associated restrictions (i.e., lack of site access by third parties), the depth of water, the physical characteristics of Site sediments, and the quality and quantity of surface water and sediment from upstream areas. A discussion of these Site characteristics is provided in the following subsections.

Factors external to the Site can also impact ecological receptors on-Site. Two fish kills were reported in Patrick Bayou on September 20, 1990 and January 20, 2003; the specific causes for the fish kills are listed as unknown on the Texas Parks and Wildlife Department (TPWD) reports and may have been related to high temperature and/or low dissolved oxygen.

2.1.1 Physical Description of the Site

Patrick Bayou discharges into the south side of the Houston Ship Channel (HSC), approximately 2.3 miles upstream of its confluence with the San Jacinto River (Figure 1-1). To support consistent spatial referencing, the Site is segmented by Stations from the mouth of Patrick Bayou at its confluence with the HSC (Station PB-000[1]), up to the Site boundary at the culverts under State Highway (SH) 225 (Station PB-102). These Stations provide the approximate linear distance from downstream to upstream in hundreds of feet (e.g., Station PB-102 is approximately 10,200 linear feet from the mouth of Patrick Bayou). The extents of the Site are shown on Figure 2-1.

Upstream drainages that flow into the Site from the south side of SH 225 are largely concrete-lined and serve as the drainage system for the City of Deer Park. City-permitted wastewater discharge also enters the Site drainage system in this area, approximately 75 feet south of SH 225 near Bayou Station 120[2] (Figure 2-1).

[1] PB – 'Patrick Bayou'

[2] Bayou Station refers to the distance from the mouth of Patrick Bayou in hundreds of feet (i.e., Bayou Station 120 is approximately 12,000 feet [120 x 100 feet] from the mouth of Patrick Bayou).

In addition to the City-permitted wastewater discharge, an urban developed area is located within the stormwater watershed that drains through Patrick Bayou. This watershed is comprised of paved surfaces (e.g., roads, parking lots), railroads, commercial/industrial facilities, recreational areas (e.g., athletic fields, golf courses), agricultural/undeveloped areas, and residential areas. Review of readily available information for this area in Federal and State databases identified 130 facility registrations, and numerous other retail/commercial/industrial facilities that can potentially discharge chemical and non-chemical stressors to the Site.

Approximately 1,800 feet of the primary channel downstream of SH 225 flows through concrete culverts before reaching the southern boundary of the Site near Bayou Station 102. The upstream boundary of the Site is defined as the confluence of the concrete culverts and an open gunite-lined channel. The gunite-lined channel—consisting of an earthen bottom and steep gunite-stabilized banks—extends north (downstream) and ends near an east-west trending railroad crossing near Bayou Station 80. Downstream of the gunite-lined portion of the Site, the channel is composed of natural and armored banks and a mud bottom. The lower portion of the Site is tidally influenced. The East Fork, which receives industrial discharges from numerous sources, enters the Site approximately midway between SH 225 and the HSC near Bayou Station 65 and is the only significant tributary of the Site.

Public access to the Site for recreational activity (e.g., fishing, swimming) is restricted by physical barriers (e.g., pipe crossings and a bridge approximately 1,200 feet upstream of the mouth of Patrick Bayou) and institutional controls (e.g., plant security). A regional health advisory is in effect to limit fishing.

The Site is a net depositional area over annual time scales, with approximately 55 percent to 60 percent of the sediment load entering the Site from the surrounding watershed being deposited within the Site. Net sedimentation rates are spatially variable at the Site, with values ranging from less than 0.1 centimeters [cm]/year to over 2 cm/year.

2.1.2 Proposed Detention Basin

To improve the floodplain storage volume in the Patrick Bayou system, the City of Deer Park and the Harris County Flood Control District jointly purchased approximately 35 acres of undeveloped property located south of SH 225, west of East Boulevard and east of Deer Park Gardens Section Two. Appendix B contains figures that show the location and plan for the proposed detention basin.

The proposed detention basin is intended to alleviate flooding on Patrick Bayou during a significant rain event (i.e., 100-year storm event). A 300-foot-long lateral weir allows stormwater runoff to enter the detention basin and a 36-inch reinforced concrete pipe controls the flow leaving the basin. The proposed in-line weir structure creates a backwater condition to direct higher stage flows into the detention basin rather than continue down the channel, but allows the lower stage flows to pass through a 6-foot-by-5-foot box culvert. As the basin fills, the head across the weir gets smaller until it is equal to the channel. In this case, the basin is full after the peak of the hydrograph has passed. As the surface water elevation in Patrick Bayou recedes following the high flow event, water will flow out of the detention basin and back into the channel across the weir.

The proposed improvements produce lower water surface elevations downstream of the basin, with a projected maximum head reduction of 3.75 feet.

Construction of the detention basin would reduce flow spikes in Patrick Bayou, which may provide the following benefits to Patrick Bayou:

- Allow sediment suspended within surface water during "normal" rain events to enter Patrick Bayou and assist in Monitored Natural Recovery (MNR). This potential effect will need to be re-evaluated after construction of the detention basin.
- Provide a buffer during "significant" rain events, reducing erosional forces on Site sediments, thereby increasing net deposition of sediment on-Site.

2.1.3 Bathymetry and Topography

A bank-to-bank bathymetric survey was conducted in 2005 by Gahagan and Bryant Associates, Inc. (GBA) for the Site and areas immediately upstream (south of SH 225) and downstream (within the proximal portions of the HSC). The results of this survey are shown in Figures 2-2 and 2-3. The upstream and upper portion of the Site (from the Deer Park Waste Water Treatment Plant [WWTP] outfall to the end of the gunite-lined channel) has a significantly higher hydraulic gradient (about 10 feet of elevation change over 5,000 linear feet) when compared to the middle and lower portions of the Site (less than 1 foot of elevation change over 8,000 linear feet).

The channel base elevation between Stations PB-037 and PB-080 (the downstream limit of the gunite-lined channel) generally is not deeper than -3 feet referenced to the North American Vertical Datum of 1988 (NAVD 88). Bank slopes in this area are relatively flat, and transitions between the channel and shoal/deposition areas are poorly defined. Downstream of Station PB-037 to Station PB-028, the bank slopes are steepened slightly, with channel elevations reaching -6 feet NAVD 88. The channel widens downstream of Station PB-028 prior to its intersection with the HSC, and areas of shoaling/deposition and channel flow are more clearly defined. Near the two small islands in the lower portion of the Site (PB-017), the primary channel alignment is offset toward the east bank and transitions to the west bank of the Site. Channel elevations between PB-028 and PB-017 ranges between -2 and -4 feet NAVD 88. Downstream of PB-017, channel elevations generally reach between -4 and -6 feet NAVD 88. The bottom elevation at the Site boundary ranges between -6 and -8 feet NAVD 88.

Stream bank heights in areas with bulkheads and riprap are generally steep with top of bank elevations exceeding 9 feet NAVD 88. Areas without bank modifications, which include much of the middle section of the Site, typically have low, sloping banks with bank elevations less than 6 feet NAVD 88. Bank cover in areas without riprap or bulkheads is generally mowed grass with some low shrubs and bare earth. In many areas, industrial facilities and impervious surfaces such as parking lots and roads are located adjacent to the banks of the Site.

The Patrick Bayou watershed was delineated into three sub-basins to evaluate runoff from the watershed to the Site inflow locations, which are located at three Stations identified for the October 2006 field survey. The U.S. Geological Survey (USGS) digital-raster graphic image of the surrounding watershed, which was obtained during 1999 to 2000, contained contour elevation data that were used to estimate the boundaries of each sub-basin. Figure 2-4 shows the results of the sub-basin delineations for inflows located at Stations

PB-075 (sub-basin 1), EF-005[3] (sub-basin 2), and PB-012 (sub-basin 3). The total area of the Patrick Bayou watershed is 2,775 acres, with sub-basins 1, 2, and 3 representing 69 percent, 11 percent, and 20 percent of the total watershed area, respectively.

2.1.4 Sediment Physical Characteristics

The geotechnical characteristics (i.e., density, strength, and compressibility) of the sediments at the Site are important considerations in determining what remedial technologies and remedial alternatives are feasible. Detailed results of the sediment geotechnical characterization are provided in the *Geotechnical Data Report* (Anchor 2008) and are summarized in this section.

Soft surface sediment thickness was delineated by push probing (Anchor QEA 2012a). These soft sediments have been shown to contain the highest concentrations of COPCs compared to the underlying Beaumont Formation Clay, which is generally free of elevated concentrations of COPCs (see Section 2.3.3 below). Soft surface sediment thickness ranges from less than 2 feet to approximately 12 feet at the Site (Figures 2-5 and 2-6).

Geotechnical core samples were collected from six locations at the Site and sent to a laboratory for additional classification testing (Anchor 2007b; Anchor 2008). Table 2-1 presents the depths of the geotechnical cores and a summary of the results of the laboratory geotechnical classification testing for these samples.

The in-situ undrained shear strength of the surface sediment was measured over several depth intervals using vane shear tests (VSTs) at several locations at the Site and at one location in the underlying Beaumont Formation Clay. The measured undrained strength increases with increasing depth below the mudline, which indicates that the deeper sediment is consolidated by the load of the shallower sediment. Peak undrained shear strength of the sediments ranged from 15 to 375 pounds per square foot (psf), with a median value of 49 psf. Residual undrained shear strength of the sediment ranged from 5 to 113 psf, with a median value of 15 psf. The shear strength required for cap support is a function of

[3] EF – 'East Fork'

several variables, including the construction sequence and duration, and the design cap thickness, whether some or all of the cap is submerged, and the desired factor of safety. An example 2-foot thick aggregate cap placed in a single lift would require sediment shear strength in the range of 70 to 250 psf for a range of typical factors of safety[4]; softer sediments would thus likely require staged construction and cap placement in thinner lifts to achieve the target factor of safety. Thinner caps (such as concrete armor form) require correspondingly lower shear strength. An example 6-inch thick concrete armor form cap would require sediment shear strength in the range of 20 to 60 psf to achieve an appropriate factor of safety.

An undisturbed core sample of the underlying Beaumont Formation Clay was collected at Station PB-030 and was submitted for laboratory hydraulic conductivity testing in accordance with ASTM D 5084. The hydraulic conductivity of the Beaumont Formation Clay was measured to be 9.8E-08 cm/s, which indicates there is negligible risk of COPCs migrating from overlying soft sediments into underlying materials.

2.2 Waterway Uses

The Site serves primarily as drainage of municipal stormwater and treated wastewater effluent from the City of Deer Park, located upstream of the Site. Additionally, industrial stormwater outfalls drain into the Site from the three facilities on the banks, and from Praxair and Rohm and Haas on the East Fork. The following sections discuss the waterway uses identified for the Site.

2.2.1 Adjacent Facilities and Infrastructure

The land use type and parcel boundaries surrounding the Site are displayed in Figure 2-7. Each parcel boundary adjacent to the Site also includes the relevant owner information, provided by the Harris County Appraisal District. Figure 2-7 shows the Site is bounded on the west bank by Shell's Deer Park refinery and chemical plant, and on the east bank, by

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[4] The range of values given for shear strength covers a range of possible cap configurations, as well as factors of safety. The lower end of the range reflects a submerged cap, which would apply less load to the existing sediment, whereas the higher end of the range reflects higher factors of safety and/or caps where a significant portion of the cap material is above water.

Lubrizol's chemical plant, and OxyVinyls' chemical production facility. A portion of the OxyVinyls facility will be decommissioned but will maintain some industrial uses (e.g., chemical transport and handling, and administrative, laboratory, and engineering services) and all of these facilities will continue with industrial operations and similar land use for the foreseeable future.

2.2.2 Existing Structures

Several fixed structures cross the Site (Figures 2-8 to 2-10). A bridge crosses Patrick Bayou from the OxyVinyls facility to a ship offloading area along the channel near the confluence with the HSC. A bridge partially crosses the Site at Station PB-057 (approximate) between the Shell and OxyVinyls facilities, and an overhead, pile supported pipe rack is present approximately 300 feet upstream of this location. There are several overhead pipe racks, a vehicle bridge, and a rail bridge that cross the Site at Stations PB-079 to PB-080.5 (approximate). Additional overhead pipe racks cross the Site at about Station PB-095. Outfalls are present at several locations along the banks of Patrick Bayou (Figures 2-8 to 2-10; Table 2-2). All of these structures physically limit access to the Site by water vessel from the HSC. The channel has concrete lined slopes between Station PB-081 and the upstream end of the Site (Station PB-102).

In addition to the multiple bridge and utility crossings, there are many shoreline structures (e.g., catwalks, sheetpile walls) along the banks of the Site. Overall access to the Site is restricted by the adjacent structures and surrounding facility security systems. The effects of these restrictions are significant and will be considered during remedial planning.

2.2.3 Ecological Functions

As indicated above, the Site is bordered by industrial facilities with a built upland environment. The aquatic habitat at the Site is largely channelized and armored, which leads to limitations in its capacity to serve ecological functions. However, some areas of the Site are less modified and allow use by several species. Therefore, there are some ecological functions provided by the Site, including habitat for bottom dwelling species (e.g., benthic and epibenthic), open water species (e.g., fish), and wildlife.

While tidal ranges are small, flow characteristics and bottom substrate conditions at the Site heavily influence animals inhabiting the water column and the sediment surface. Under typical conditions, Patrick Bayou is a low-gradient tidal stream influenced by daily tides of 1.5 feet or less. However, moderate and heavy precipitation events can produce significant flows in Patrick Bayou, causing rapid fluctuations in salinity, temperature, dissolved oxygen, velocities, and suspended sediment loads. Conversely, sustained drought can result in significantly higher salinity and temperature regimes and depressed dissolved oxygen levels within tidal streams such as Patrick Bayou. As described in Section 2.1.2, the proposed detention basin is expected to mitigate flow spikes and may change overall sedimentation at the Site.

These environmental conditions may significantly influence benthic species that have close associations with sediment and limited home ranges. Studies of the Site evaluating the condition of the benthic community have shown wide variability in benthic species presence and diversity at the Site (Anchor 2006). Thus, while a benthic community, which provides a base for the food chain within tidal streams, is present, it likely reflects both changes in physical Site conditions, as well as CERCLA related releases (i.e., COPC) in Site sediments. Fish and shellfish occur in Patrick Bayou in various aquatic zones, natural or modified, throughout the Site. Water depths are shallow (typically less than 3 feet during normal tidal conditions), which will generally preclude fish that prefer deeper water. In addition, fish distribution and abundance is expected to be associated with the availability of appropriate prey items, temperature, and salinity regime as required for different species. Shellfish, such as juvenile blue crab[5] and shrimp, are generally found at the relatively higher salinity near the HSC and are not found in significant numbers in upstream areas of the Site (generally upstream of the East Fork Tributary). The steep gradient and larger grain size materials (gravels and cobbles) in the gunite channel, also limit benthic habitat in upstream areas. Given the size of the Site, wider-foraging or migratory fish would not be expected to spend significant time within the Site. However, they may occasionally forage within Patrick Bayou. Smaller size class fish that are known or expected to occur within Patrick Bayou include Gulf killifish (*Fundulus grandis)*, sailfin molly (*Poecilia latipinna)*, sheepshead

[5] Adult blue crab which can tolerate a higher range of salinity can be found farther upstream (near the gunite channel) than juvenile blue crab under the same conditions.

minnow (*Cyprinodon variegatus)*, juvenile mullet (*Mugil* spp.), juvenile croaker (*Micropogon undulates)*, juvenile Gulf menhaden (*Brevoortia patronus)*, juvenile hardhead catfish (*Ariopsis felis)*, and juvenile sand seatrout (*Cynoscion arenarius)*. Larger size class fish that are known or expected to occur include mullet, hardhead catfish, gar (*Lepisosteus* spp*.)*, croaker, and black drum (*Pogonias cromis)*. Examples of shellfish and crustaceans expected or known to occur include shrimp (*Penaeus* spp.), fiddler crab (*Uca* spp.), oyster (*Crassostrea virginica*), and blue crab (*Callinectes sapida*; adult and juvenile).

Wildlife habitat at the Site consists of less modified areas of bank and riparian zones of the downstream portions. Riparian conditions range from maintained turf grass to shrub/scrub with sparse tree cover. Natural banks are generally low and gradually sloping, while banks that have been armored are steep and high. Emergent vegetation is largely absent from the Site.

Wildlife at the Site would be limited to species associated with aquatic habitats. Wading birds (e.g., herons), waterfowl, shorebirds, and piscivorous birds (e.g., belted kingfisher) have been observed at the Site. Given the industrial nature of the upland habitat, lack of riparian cover, and modified nature of the shoreline, habitat to support terrestrial mammals is limited. Thus, species that may be present (or have been observed) would include those with limited ranges and urban-adapted characteristics such as raccoon, muskrat, nutria, mice, and rats.

2.2.4 Future Use of Waterway

The foreseeable future use of the waterway is consistent with its current use as a primary stormwater drainage feature for the City of Deer Park and for the three industrial facilities on the banks of the Site and for the industrial facilities upstream of the Site on the East Fork. No change is anticipated to the future use of Patrick Bayou.

2.3 Nature and Extent of Indicator Chemicals

ICs are often selected during an RI to streamline the assessment of chemicals that are likely to be of greatest concern (USEPA 1998). ICs are selected to represent chemicals that are persistent, and/or toxic, and that are expected to substantially contribute to human health or environmental risk posed by a certain site. In addition, it may be necessary to identify ICs to simplify the alternative development and screening phases.

The primary IC class at the Site is PCBs based on potential risk to wildlife and benthic invertebrates. Total PAHs, BEHP, and lead are also associated with some risk to benthic invertebrates and are secondary ICs (Anchor QEA 2013).

2.3.1 Surface Sediment

Surface sediment samples from 0 to 10 cm below ground surface (bgs) were collected at 66 locations within the Site in 2009 as part of the RI. These data were collected to provide the basis of the subsequent risk assessments for the Site. The distribution of sample locations is provided in Figures 2-11 and 2-12. The distribution of PCBs[6] is mapped in Figure 2-13.

2.3.1.1 Upstream Surface Sediment Samples

Surface sediment samples were collected at nine locations outside of the Site boundary in 2006 and 2011 (Figure 2-14) to gain an understanding of the relatively recent concentrations of COPCs that may enter the Site from upstream sources outside of the influence of any industrial activities adjacent to the Site. Four samples were collected in 2006: one from the East Fork tributary, two from upstream of the culverts below SH 225, and one from a drainage ditch east of the upstream end of the culverts. All four samples were collected from the 0 to 2 cm sediment interval. In 2011, one sample was collected from each of the five culverts below SH 225. All samples were collected from the 0 to 10 cm interval, except for the sample from Station PB-119.1, which was collected from the 0 to 30 cm interval.

The IC concentrations in surface sediments upstream of the Site are illustrated in Figure 2-14. PCBs were only analyzed in samples collected from the culverts under SH 225 (PB-119.1 through PB-119.5). Total PCB congener concentrations ranged from 0.0084 milligrams/kilogram (mg/kg) (PB-119.3) to 0.017 mg/kg (PB-119.5). Total PCB toxic equivalent (TEQ) based on factors for mammalian receptors ranged from 0.21 ng/kg

[6] As the sum of 209 congeners.

(PB-119.4) to 0.48 ng/kg (PB-119.5). Total PCB TEQ based on factors for avian receptors ranged from 1.6 ng/kg (PB-119.4) to 3.31 ng/kg (PB-119.2). Because these data indicate there is a current ongoing load of PCBs entering the Site from urban runoff, PRAOs should acknowledge the potential long-term impacts of this uncontrolled source as part of the remedial alternative planning.

2.3.2 Subsurface Sediment

Subsurface samples, defined as samples collected from intervals greater than 10 cm bgs, were collected at 11 locations (Figure 2-15). The distribution of total PCBs[7] is shown in Figure 2-16.

Stations PB-057, PB-048, and PB-042 have the highest subsurface maximum total PCB concentrations of 400, 180, and 200 mg/kg; respectively. Subsurface total PCB concentrations decrease downstream of Stations PB-057 to PB-003, which has a subsurface maximum total PCB concentration of 3.6 mg/kg. Upstream of Station PB-057, subsurface total PCB concentrations do not exceed 43 mg/kg. It should be noted that the depth of soft sediments in four of the five cores collected upstream of Station PB-057 did not exceed 85 cm bgs. Subsurface maximum total PCB concentrations for most cores are between 50 to 80 cm bgs. With few exceptions, the lowest total PCB concentrations are observed in sample intervals near the contact with the Beaumont Formation, indicating the vertical extent of contamination is defined.

The vertical profiles of PCBs (Figure 2-16) and other COPCs in Patrick Bayou show positive changes at the Site in terms of ongoing reduction of surface sediment concentrations. The vertical profiles of other COPCs, including PAHs and BEHP, show that the concentrations of these COPCs at the surface and available to potential surface receptors have also significantly declined over time, since the peak of contaminant loading (Anchor 2007b). Although the peak concentration varies by COPCs and location, the vertical profiling and associated radiometric analyses conducted in 2006 indicate that most loading for these COPCs occurred more than 30 years ago (92 cm and deeper; Anchor 2007b). These observations indicate

[7] Only PCB Aroclors were analyzed in subsurface sediments. Therefore, PCB TEQ is not presented.

historical or legacy discharges are responsible for the bulk of the COPCs (especially PCBs) observed at the Site and that natural attenuation of COPCs should continue at the Site to lower potential risk to surface receptors.

PCBs (along with other COPCs identified for the Site) have higher concentrations at depth and will require consideration during the development of the FS. Removal of sediment, which was considered in combination with ex-situ treatment technologies and disposal options, would temporarily expose sediments with greater concentrations of COPCs; therefore, future evaluations of removal conducted as part of the FS will consider the vertical extent of PCBs and the other COPCs.

2.3.3 Groundwater

This section provides a summary of relevant groundwater-related activities that have been conducted at each facility, evaluated within the context of the nature and extent of contamination at the Site.

Information regarding the Patrick Bayou area hydrogeologic setting and investigations has been obtained primarily from reports prepared by adjacent facilities. Specifically, Shell, Lubrizol, and OxyVinyls (Figure 2-7) have conducted detailed groundwater-related investigations pursuant to the Texas Risk Reduction Program (TRRP) and Voluntary Cleanup Program (VCP) initiatives overseen by the Texas Commission on Environmental Quality (TCEQ) (Shell 2009, Lubrizol 2011, and Weston 2007). The focus of several of those investigations was to evaluate and quantify the potential for soil and groundwater from the facilities to impact sediment and surface water within the Site.

As discussed in the PSCR (Anchor 2006), each facility carried out groundwater investigations in parallel with investigations in Patrick Bayou under their respective ongoing TCEQ-regulated TRRP program. Furthermore, corrective actions have been implemented and continue to function at each adjacent facility to prevent groundwater interaction with Patrick Bayou. The interaction between potentially contaminated groundwater and the Patrick Bayou sediment and surface water has been considered, based on data provided from the individual facility's TRRP projects. Since the submission of the PSCR in 2006 (Anchor 2006), each facility has submitted groundwater-specific evaluation reports (Shell 2009, Lubrizol 2011, and Weston 2007). These reports provide data and evaluations that indicate groundwater from each facility has insignificant measurable interaction with and contributes no toxicity to Patrick Bayou sediments/surface water. Based on these evaluations and outcomes, groundwater interaction between sediments and surface water are not considered a pathway of concern in regard to remedial planning for sediments at the Site.

2.4 Physical Conceptual Site Model

Several factors related to the physical CSM, especially as they relate to the hydrodynamic conditions at the Site, should be considered during evaluation of remedial approaches. Freshwater flow into the Site is significantly affected by runoff from the surrounding watershed during precipitation events. The Site watershed is relatively small and primarily consists of industrialized and urbanized areas and, thus, runoff during a rainstorm occurs rapidly. The hydrologic system may be described as flashy, with runoff to the Site increasing rapidly after a precipitation event begins, and similarly, runoff decreases quickly after rainfall ceases. This behavior has a significant effect on the Site hydrodynamics, as well as the external sediment loading from the watershed to the Site. The proposed detention basin, described in Section 2.1.2, may mitigate the periodic flow spikes and associated erosion of sediment.

Patrick Bayou is hydrodynamically connected to the HSC, with observed salinity values ranging from 10 to 20 parts per thousand (ppt) in the HSC. Estuarine circulation does occur within the Site, with gradients in water density, due to differences in salinity, affecting currents to some extent. However, due to its morphology and bathymetry, Patrick Bayou has minimal vertical stratification and two-layer flow.

During conditions of low freshwater inflow, circulation patterns are dominated by diurnal tidal currents within Patrick Bayou. Tidal range is relatively low (i.e., typically 1-2 feet), but significant areas of mudflats in the inter-tidal zone of the Site may be exposed during ebb tide conditions. Salinity levels at the Site are similar to that of the HSC, with minimal horizontal gradients throughout most of the Site during these low flow conditions.

During precipitation events with high freshwater inflow, circulation within the Site reacts relatively quickly due to the flashy nature of the surrounding watershed. High-flow events typically occur over hourly timescales, with sustained high freshwater inflow, rarely lasting for more than 24 hours during a single event. These events can have significant effects on Site hydrodynamics, which may be tempered in the future after installation of the previously described detention basin. Flood waters can inundate inter-tidal zones and floodplain areas above the normal inter-tidal high-water level within the Site. Freshwater inflow dominates tidal currents within the Site during a high-flow event. Most of the Site will contain freshwater, with large volumes of freshwater inflow pushing most of the salty water out of the Site. After a high-flow event is over, the salinity within the Site slowly increases as tidal processes transport brackish water into the Site from the HSC, with the return to low-flow salinity conditions typically occurring over a period of many days (Anchor QEA 2011).

As mentioned above, diurnal tides and the relatively low tidal elevation ranges can affect estuarine circulation in Patrick Bayou. In addition, water surface elevation conditions due to non-tidal processes in the HSC and Galveston Bay can have a significant effect on Site hydrodynamics. Two important non-tidal processes are: 1) storm surges during hurricanes/tropical storms; and 2) drawdown during offshore (northerly) wind storms.

The sediment bed in Patrick Bayou is primarily composed of cohesive (i.e., muddy) sediment, with isolated areas of non-cohesive (i.e., sandy) sediment. An exception to this characterization is in the area of the gunite-lined channel where the side slopes are cement-stabilized and the bottom contains hard sediment and debris. Long-term average net sedimentation rates (NSRs) within the Site are spatially variable. Generally, NSR values decrease when moving from the upstream portion of the Site, near the freshwater inflows, toward the HSC, but there is significant variability in NSR at localized spatial scales.

The results of a hydrodynamic and sediment transport modeling study (Anchor QEA 2011) were used to develop an improved understanding of sediment transport processes within the Site. Additional modeling may be required to assess the potential effect of the proposed detention basin on sediment transport. Results of the empirical and modeling analyses were used to develop the following conceptual model for sediment transport in Patrick Bayou:

- As a whole, Patrick Bayou is net depositional over annual time scales, with approximately 55 percent to 60 percent of the sediment load entering the Site from the surrounding watershed being deposited within the Site.

- NSRs are spatially variable in Patrick Bayou, with values ranging from less than 0.1 cm/year to over 2 cm/year.
- Bed erosion is typically an episodic process that is most pronounced during high-flow events. During the 100-year high-flow event (i.e., event with 1 percent chance of occurring in a given year), net erosion occurs in approximately 65 percent of the total bed area and the majority of the net erosion is less than 6 cm. During the 2-year high-flow event (i.e., event with 50 percent chance of occurring in a given year), net erosion occurs in about 45 percent of the total bed area and erosion depths are less than 2 cm. Generally, erosion at the Site, even during high-flow events, only affects surface-layer sediments and is limited to bed depths that represent relatively recent deposition. As noted in Section 2.1.2, construction of the proposed detention basin may mitigate the occasional high flows and associated erosion. Additional modeling would be required to assess the potential effect of the proposed detention basin.

The results of the hydrodynamic and sediment transport modeling at the Site indicate deeper sediments that have higher concentrations of COPCs are stable. There should be an ongoing reduction of surface concentrations of COPCs due to natural sedimentation at the Site, and any surface management that may involve sediment capping or stabilization should accordingly account for changes in flow velocities and scour potential.

3 BASIS FOR REMEDIAL ACTION

This section describes the development of PRAOs and provides discussion of prospective RALs against which the various remedial alternatives will be evaluated. This information, combined with the development of SMAs and considerations of ARARs, form the basis for evaluating remedial actions for the Site.

3.1 Preliminary Remedial Action Objectives

The PRAOs for the Site were developed based on previous work jointly conducted by the JDG, USEPA, TCEQ, other stakeholders, in consideration of USEPA guidance, and were originally presented and discussed in the PSCR (Anchor 2006). The PRAOs broadly define the overall goals of the project and recognize the industrial and commercial nature of the Site and surrounding areas. Current and future land use should be considered in defining the RAOs for a site (USEPA 1995, 1998). The RI/FS Data Quality Objective (DQO) development process should also consider the land use in determining the Problem Statements and Management Goals on which the risk-based remedial investigation are based (USEPA 1995, 1998).

In the case of Patrick Bayou, the watershed has been extensively altered for commercial, industrial, and waste management purposes. A decision consequence analysis (DCA) process (fully described in Appendix F of the Preliminary Site Characterization Report [Anchor 2006]) included JDG, stakeholder, and agency representative participation as part of a Patrick Bayou DCA Working Group. This Group evaluated the current conditions of the Bayou, controllable and uncontrollable stresses to the Bayou, current and future uses of the Bayou, and attempted to identify the long-term goals for improving the functions the Site (e.g., industrial and municipal discharge watercourse, ecological habitat). The findings of that Group were that the potential ecological functions and associated human uses would be reduced from natural conditions at the Site even if contamination were absent. In addition, anthropogenic sources of contamination, such as urban and industrial runoff, are likely to continue to be non-point sources of contamination to the Site that will not be addressed by on-Site management actions.

The urban and industrial nature of the Site and the long-term commitment to these uses must be considered in selection of an overall management goal. Given the physical setting of the Site, the overall PRAO is to protect populations of sensitive ecological receptors that may feed at the Site and prevent measurable degradation of downstream resources from Patrick Bayou sediment relocation. Protection and/or restoration of resources within the Site itself will be assessed in the context of the land use activity within the Site watershed.

The PRAOs, as stated in the PSCR (Anchor 2006) are:

- Primary Objective
  - Prevent adverse effects on wildlife species that may feed at the Site and prevent measurable degradation of downstream ecosystems, as a result of the transport of contaminated sediment from Patrick Bayou.
- Secondary Objectives
  - Achieve measurable improvements in total ecological system functions.
  - Maintain remedy flexibility in response to remedy monitoring data.
  - Minimize long-term human interaction needed to maintain the remedied system.

Subsequent to the PSCR and based on the conclusions of the BERA (Anchor QEA 2013), protection of benthic invertebrates from sediment toxicity associated with PCBs and secondary COCs (PAHs, lead, BEHP) was identified as an additional PRAO. This PRAO is considered a primary objective.

3.2 Application to the Remedial Investigation/Feasibility Study

The primary PRAOs focus on managing adverse effects on wildlife and benthic invertebrates due to sediment toxicity primarily associated with PCBs. The BERA (Anchor QEA 2013) identified potential unacceptable ecological risks to piscivorous and shorebird populations. Baseline PCB TEQ HQs for these receptor groups are equal to 1.0 and 1.7 for spotted sandpiper and belted kingfisher, respectively. However, uncertainty analyses indicate that HQs for these COPC-receptor pairs may be above or below the threshold of concern (HQ = 1.0) depending on the assumptions used to characterize risk. Thus, within the ranges of exposure and effects variables evaluated, risks may not exceed a threshold of concern for individuals exposed to PCBs in Site media.

Using a weight of evidence approach that included three lines of evidence (sediment chemistry, sediment toxicity tests, and benthic community data), PCBs were identified as a COC for the benthic community in the BERA (Anchor QEA 2013). Areas of probable risk were identified based on a consensus of the three lines of evidence evaluated. However, the available data did not support a quantitative estimate of the magnitude of risk within these areas.

Incremental risk to benthos and wildlife is driven primarily by exposure to PCBs. Although the BERA contained no specific risk management recommendations, it recommended that risk management based on risks to ecological receptors should be considered within the overall context of other risk management considerations (e.g., water quality standards) and consistent with the PRAO defined above.

The designated uses of the Site, as defined by TCEQ in Title 30, Part I, Chapter §307.10, Appendix A of the *Texas Administrative Code*, include industrial discharge and navigation; however, it is also recognized that the Site provides ecological habitat and benefit to a variety of receptors (e.g., benthos, fish, birds, and small mammals). The physical conditions of the Site, including natural variations in stream flow, bed configuration and substrate, hydraulic gradient, grain size, and the land uses (which are reflected in parameters such as salinity and dissolved oxygen) will prevent restoration of the Site to a uniform measure of ecological function. Because of these limitations, the ultimate focus of the RI/FS is to develop a strategy for producing beneficial changes by identifying and managing the controllable stressors on the Site ecosystem.

The secondary PRAOs focus on providing a positive rate of improvement in regard to system function and lowering of ecological risks through an efficient process. Efficiency is measured based on time, area, cost, and overall effort in both the investigation and remediation of the Site.

Due to the absence of potential adverse effects to human health from contaminants at the Site, PRAOs specific to protection of human health are unnecessary. As noted in the BHHRA (Anchor QEA 2012b), the entire shoreline of the Site is lined by three industrial properties: Lubrizol, Shell, and OxyVinyls. For safety and security reasons, these industries located along the shoreline of Patrick Bayou restrict public access 24 hours a day, 7 days a week and require that visitors are escorted while on-Site. There are also several above-ground industrial pipelines crossing the bayou near the confluence of the Site and the HSC that effectively restrict access by boat. Furthermore, the Captain of the Port of Houston-Galveston has established security zones for certain areas within the Houston-Galveston area that include the portion of the HSC where Patrick Bayou enters. The security zones exclude recreational/unauthorized vessels from these areas, which prevents or discourages access to the Site through the HSC. Therefore, the BHHRA (Anchor QEA 2012b) concluded that public access for fishing or recreation within Patrick Bayou is not considered a route of exposure to Site COPC now or in the foreseeable future. The BHHRA also made the following additional conclusions:

- The likelihood of exposure to contaminants in groundwater or air is low to nonexistent and these exposure pathways are considered incomplete.
- Unacceptable adverse risks (carcinogenic and non-carcinogenic) to workers at the facilities that may be exposed to Site sediments or surface water are highly unlikely now or in the foreseeable future.
- Due to the inaccessibility of the Site to the public, exposure to contaminants through ingestion of contaminated seafood obtained from within the Site is highly unlikely and not a complete exposure pathway. To further assess potential exposure to contaminated biota, the BHHRA evaluated the potential for off-Site fishermen to catch and consume fish that may have been exposed to Site contaminants. Using discriminant analysis, it was shown that the exposure pathway from the Site to the nearest off-Site point of exposure (i.e., San Jacinto Monument) for recreational fishermen is insignificant, and no further risk analysis was necessary for this subpopulation.

The conclusions of the BHHRA are also reflected in an earlier document by the Texas Department of Health (TDH 2003). The TDH, under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR), reviewed available environmental information for the Site and evaluated the primary pathways through which people might possibly come into contact with Site-related chemicals. As summarized above, those potential exposure pathways included groundwater, sediment, surface water, seafood, and air. TDH concluded people are not coming in contact with Site-related chemicals; therefore, the Patrick Bayou NPL Site does not pose a public health hazard.

3.3 Source Control

Current or historical industrial and anthropogenic activities and processes that may lead, or may have led to either point or nonpoint releases to Patrick Bayou include petroleum refining, storage, and distribution; chemical manufacturing and formulation; urban development and use; agricultural applications; industrial shipping and use of the HSC; dredging of the HSC; industrial operations along the HSC; electrical substation operation and maintenance; and sewage treatment.

3.3.1 Discharge Outfalls

Several permitted discharge outfalls enter the Site, the East Fork tributary, or the HSC near the Site. Descriptions of these outfalls and their locations are provided in Table 2-2 and Figures 2-8 to 2-10, respectively. There are no known active discharges that add ICs or other chemicals to the Site above their National Pollutant Discharge Elimination System (NPDES) discharge allowances or above typical urban background loading.

3.3.2 Groundwater Discharge

Groundwater from shallow water-bearing zones naturally discharge into Patrick Bayou. The discontinuous nature and low hydraulic conductivity of Site stratigraphy produces poor lateral continuity of the shallow water-bearing units across the Site. As summarized in Section 2.3.3, groundwater interaction between sediments and surface water are not considered a pathway of concern in regard to remedial planning for sediments at the Site based on extensive evaluations by each surrounding facility under the TRRP and VCP, as administered by TCEQ.

3.3.3 Spills

A review of spill reports maintained by the TPWD from 1958 to 2005 (Denton 2006) revealed no documented spills in Patrick Bayou during that time. Numerous spills have occurred in Segment 1006 of the HSC. Spills in the HSC could potentially travel via surface water into Patrick Bayou. In addition, undocumented or historical spills (prior to 1958) are potential sources. Finally, small spills on the adjacent roadways (e.g., SH 225, etc.) could also be transported and discharged to Patrick Bayou.

3.3.4 Bank Erosion

Soils or fill possibly containing COCs may erode from unprotected banks of Patrick Bayou and enter surface water or sediments of the Site. Portions of the Site banks are covered with bank stabilization material, which inhibit erosion. Flow in Patrick Bayou is generally sluggish and erosive forces on the unprotected banks of Patrick Bayou are likely to only be significant during storm events, which will be reduced in the future after the construction of the detention basin.

3.3.5 Atmospheric Deposition

Nearly all surface water bodies are exposed to potential deposition of chemicals in the atmosphere. Chemicals deposited to surface waters of Patrick Bayou may come from local and distant nonpoint and point sources. Chemicals that are deposited to the surface water may become dissolved and adsorbed to particulates, or may adsorb to sediments. PAHs, released into the atmosphere from local and distant sources are chemicals that are often associated with atmospheric deposition to surface water.

3.3.6 Houston Ship Channel Interaction

Patrick Bayou is tidally influenced and the tidal fluctuation produces an interaction between Patrick Bayou water and sediments. In addition, HSC water is used as non-contact once-through cooling water at the OxyVinyls facility and discharged into Patrick Bayou at outfalls 002 and 003, located approximately between segments PB-036 and PB-048. Cooling water is no longer required for the OxyVinyls facility; however, minimal flows from the HSC are maintained through the system to keep the pumps and piping in proper working order.

3.3.7 Upstream Sources

Land use in the watershed upstream of SH 225 is primarily residential, undeveloped/pasture, and commercial/industrial. City-permitted wastewater discharge enters the Site drainage system in this area, approximately 75 feet south of SH 225 near Station PB-120 (Figure 2-1).

In addition to the City of Deer Park WWTP, an urban developed area is located within the stormwater watershed that includes paved surfaces (i.e., roads, parking lots, etc.), commercial/industrial facilities (with permitted, unpermitted, and accidental releases), railroads, recreational areas (i.e., sports fields, golf courses, parks, etc.), agricultural/undeveloped areas, and residential areas. Review of information available for this area identified 130 facility registrations identified within 21 Federal and State databases, and numerous other retail, commercial, and industrial facilities that have the potential to contribute stressors to the Site. This information demonstrates that there are numerous facilities that currently release, have experienced a historic release, or have the potential to release contaminants to the stormwater system, along with loading from other urban sources that may have a direct impact on the quality of the Site. The JDG does not control these facilities; however, the impact from these upstream sources should be considered when assessing the current quality of sediment and surface water at the Site and in developing remedy end point criteria.

Upstream drainages in the City of Deer Park are concrete-lined open drainage ditches, and chemicals in surface water and soil runoff from these upstream sources would quickly reach the Site. Metals, PAHs, pesticides, and nutrients are frequently associated with urban runoff to surface water and sediment. Runoff from agricultural, recreational, and residential land frequently includes pesticides, herbicides, and fertilizers (nutrients). Some of the chemicals present in Site sediments are likely due to upstream sources entering the Site and being deposited in the various depositional zones.

As described in Section 2.3.1.1, nine samples were collected from areas upstream of the Site boundary. PCBs were only analyzed in samples collected from the culverts under SH 225 (PB-119.1 through PB-119.5). Total PCB congener concentrations ranged from 0.0084 mg/kg (PB-119.3) to 0.017 mg/kg (PB-119.5).

3.3.8 Pathway Elimination

There are no known controllable active sources of chemicals to the Site surface water or sediments based on the above information for air, groundwater, surface water, soil, active outfalls, or spills. There is likely ongoing loading of COCs and other chemicals to the Site sediments and surface water from ongoing urban runoff drainage, the WWTP at the City of Deer Park, and air deposition. Based on this outcome for source control and the available RI/FS data for sediments and surface water presented in Section 2, any potential remedial actions at the Site should be focused on controlling exposure pathways of direct sediment contact, sediment/surface water interaction, and surface water. These pathways are most effectively addressed through sediment-based remedial actions. The technologies that are evaluated in Section 4 of this document are therefore focused on sediment-based management within the Site.

3.4 Sediment Management Areas

SMAs are used to subdivide the Site into smaller areas with common characteristics. SMAs will be fully defined in the FS to facilitate the final evaluation of potential remedial alternatives. This *Remedial Alternatives Technology Screening* document presents five preliminary SMAs. The common characteristics of SMAs may affect the performance of certain remedial technologies. For example, a remedial approach like removal might not be appropriate for consideration beneath an active fixed structure where the foundation could be undermined. Thus, for example, one criterion for developing SMA boundaries is based on the presence or absence of active fixed structures. SMAs will be used for screening remedial alternatives in the FS.

Table 3-1 lists the preliminary SMA classifications developed for this document.

Table 3-1
SMA Definitions

SMA Name	Description
NS	"Nearshore" Shallow areas with limited access for water-based construction equipment, or areas accessible from the shoreline; typically 2 feet of water and shallower, and/or within 40 to 50 feet of the shoreline (assumed maximum practical reach of a long-reach excavator).
ST	"Structures" Areas beneath the footprint of fixed structures, including appropriate horizontal offsets to protect the structure during remedy implementation.
AB	"Artificial Banks" The concrete-lined channel at the upstream end of the Site.
OW	"Open-Water" All other areas within the project footprint that are not covered by the descriptions above.

SMA Name	Description
$-NE_{100}$	"Net Erosional" The Net Erosional designation is a modifying criteria that can be applied to any of the other SMA types defined above. It does not describe a specific, distinct SMA that is independent of the other SMA types previously defined. The $-NE_{100}$ modifier is used to describe SMAs that are considered to be net erosional during a 100-year flood based on the hydrodynamic model of the Site. The potential mitigating effects of the proposed detention basin, described in Section 2.1.2, have not been modeled and are not considered in the designation of $-NE_{100}$ areas.

Figure 3-1 depicts the location of these SMAs within the boundaries of the Site. It should be noted that portions of the Site downstream from the Artificial Banks (AB) area are also protected with armoring (e.g., riprap); these areas are not included within the AB SMA and are evaluated as part of the remaining SMA types. Considerations related to potential remedial actions within each type of SMA are discussed in more detail in Section 5.

3.5 ARARs

The development and evaluation of remedial alternatives will include an assessment of the ability of the remedial alternatives to address ARARs of environmental laws and other standards or guidance to be considered (TBC). Table 3-2 provides a broad summary of potential ARARs and TBCs that will be considered in the FS. The list includes certain citations that are not applicable to the Site, so as to document the basis for eliminating these regulations, standards, or guidelines from consideration. Many of the ARARs and TBCs in Table 3-2 will be relevant to only some of the remedial alternatives, but all of the requirements that may be relevant to any of the remedial alternatives are identified in the list.

Once a remedial action is selected, a detailed review of ARARs specific to the selected remedial action will be conducted and included in the *Design Analysis Report* for the selected action.

4 IDENTIFICATION AND SCREENING OF REMEDIAL AND DISPOSAL TECHNOLOGIES

This section identifies and describes the General Response Actions (GRAs), remedial and disposal technologies, and process options to be considered at the Site. Each of these elements is considered in the screening of remedial alternatives and is defined below:

- **GRAs** – Major categories of cleanup activities that could be applied to manage COCs in sediments. GRAs include natural recovery, institutional controls, containment, removal, treatment, and disposal. GRAs for the Site apply to sediment and may be used singly or in combination to satisfy the RAOs that will be developed for the Site.
- **Remedial and Disposal Technologies** – General categories of technologies within a GRA that describe a means for achieving the RAOs. For example, removal is a GRA that can be achieved using dry excavation or dredging technologies, while treatment is a GRA that can be achieved using physical, biological, or chemical technologies. Innovative technologies were evaluated, as required per USEPA guidance (USEPA 1988). The screening of treatment technologies is provided in Appendix A.
- **Process Options** – Specific processes within each technology type. Process options are selected based on the characteristics of the medium (e.g., sediment), Site conditions, and availability of technologies to address the medium or Site conditions. For this screening, a range of process options are identified to illustrate the variety of alternatives that could be implemented by a contractor during remedial construction. At this conceptual-level screening phase, eliminating certain process options may inadvertently limit potential remedial technologies from consideration in the FS or the remedial design phase. Therefore, this document primarily focuses its screening at the remedial and disposal technologies level, with some detailed discussion on process options, where it is important to note critical factors for specific process options. Some process options are identified and screened out where critical factors make the process option infeasible. Differences between process options relative to sustainability factors, such as energy usage, air emissions, and reuse of materials will be considered in accordance with the Region 6 Clean and Green Policy (USEPA 2009). These factors will be more significant, however in the detailed evaluation of remedial alternatives, which will be presented in the FS, and the remedial design.

Following CERCLA guidance, cleanup/treatment technologies are organized under GRAs that represent different conceptual approaches to remediation and include:

- Institutional Controls
- Monitored Natural Recovery (MNR) and Enhanced Monitored Natural Recovery (EMNR)
- In-situ Containment
- In-situ Treatment
- Removal Technologies
- Ex-situ Treatment
- Disposal Technologies

Tables 4-1 and 4-2 describe the GRAs, technology types, and process options potentially appropriate to the Site sediments. Applicable technologies for the treatment of Site sediments were reviewed and are summarized in Appendix A. The evaluations in Appendix A form the basis of the in-situ and ex-situ treatment sections. Additional technologies for each of the above GRAs are included alongside these treatment options to provide a comprehensive screening assessment for the methods that may be applicable to the Site. Each of the elements identified is discussed in subsequent sections of the document. Remedial technologies potentially applicable to address PRAOs are described in Section 4.3. Section 4.4 presents a screening of ex-situ treatment technologies and disposal methods that may be applicable if removal of sediment is necessary as part of a remedy.

Table 4-1
Identification of General Response Actions, Technology Types, and Process Options Potentially Appropriate for the Patrick Bayou RI/FS

GRA	Technology Type	Process Option	Section
Institutional Controls	Administrative and Legal Controls	Access and property use restrictions	4.3.1 Institutional Controls
		Informational devices (e.g., signage and fish consumption advisories)	
Natural Recovery/	Monitored Natural	Natural Sedimentation	4.3.2 Monitored Natural Recovery and

GRA	Technology Type	Process Option	Section
Enhanced Natural Recovery	Recovery	Placement of thin layer of clean cover	Enhanced Natural Recovery
In-situ Containment	Cap	Articulated Concrete Block Mat (ACBM)	4.3.3 In-situ Containment (Capping)
		Aggregate and Natural Materials	
In-situ Treatment	Physical-Immobilization	Adsorptive Amendments	4.3.4 In-situ Treatment
Removal	Dry Excavation	Soil Excavator	4.3.5 Removal
	Dredging	Mechanical Dredging	
		Hydraulic Dredging	

Table 4-2
Identification of Ex-situ Treatment and Disposal General Response Actions, Technology Types, and Process Options Potentially Appropriate for the Patrick Bayou RI/FS

GRA	Technology Type	Process Option	Section
Ex-situ Treatment	Immobilization	Solidification Stabilization (S/S)	4.4.1 Ex-situ Treatment Technologies
	Separation and Extraction	Washing	
	Thermal	Incineration	
		Thermal Desorption	
Aquatic Disposal	Confined Aquatic Disposal (CAD)	Not Applicable	4.4.2 Aquatic Disposal
	Nearshore Confined Disposal	Not Applicable	
	Open-Water Disposal	Not Applicable	

GRA	Technology Type	Process Option	Section
Upland Disposal	Landfill	Not Applicable	4.4.3 Upland Disposal
	Confined Disposal Facility (CDF)	Not Applicable	
Beneficial Use	Aquatic and Upland Placement	Not Applicable	4.4.4 Beneficial Use

The identification and screening of remedial technologies and process options generally follows the USEPA's *Guidance for Conducting RI/FS* (USEPA 1988, 2005). This evaluation includes only those technologies and process options applicable to the IC, the physical matrix, and relevant Site characteristics; therefore, only applicable technologies will be carried forward into the assembly of alternatives in the FS.

4.1 Evaluation Criteria

USEPA guidance (1988) has a number of steps in the process of selecting a preferred alternative. These include the following:

- Develop RAOs (Section 3.1 – Preliminary Remedial Action Objectives)
- Develop GRAs and identify remedial technologies (Section 4 – Identification and Screening of Remedial and Disposal Technologies)
- Screen remedial technologies (Section 4 – Identification and Screening of Remedial and Disposal Technologies)
- Assemble alternatives from the remedial technologies carried forward from the screening process (this will be done in the FS)
- Evaluate the alternatives against the nine CERCLA criteria (this will be done in the FS; see description below)

USEPA evaluation criteria used to evaluate the remedial alternatives developed in the future FS are divided into three groups based on the function of the criteria in the remedy selection. The first group consists of the threshold criteria relating to statutory requirements that each alternative must satisfy in order to be eligible for selection and includes:

- Overall protection of human health and the environment
- Compliance with ARARs

The second group consists of primary balancing criteria that are the technical criteria upon which the detailed analysis is primarily based and includes:

- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume through treatment
- Short-term effectiveness
- Implementability
- Cost

In keeping with the Region 6 Clean and Green Policy (USEPA 2009), sustainability will be incorporated into the development of remedial alternatives. The evaluation of long- and short-term effectiveness will favor alternatives that achieve RAOs with less environmental impact.

The third group is identified as modifying criteria that may be considered by USEPA in selecting a remedy and includes:

- State/Support agency acceptance
- Community acceptance

These last two criteria are assessed formally after the public comment period, although to the extent they are known, they are factored into the identification of the preferred alternative. Based on this formal consideration, the lead agency may modify aspects of the preferred alternative or decide that another alternative is more appropriate. The Remedial Project Manager will develop and maintain a thorough understanding of State and community concerns throughout the RI/FS process. This understanding is essential to prevent issues from arising that could fundamentally change the alternatives being considered after completion of the RI/FS and proposed plan (USEPA 2000).

As discussed previously, this document will screen available technologies to determine which technologies can be carried forward for alternatives development in the FS. The associated screening criteria per USEPA guidance (1988) are:

1. Implementability
2. Effectiveness
3. Cost

The screening process determines those technologies that will not be carried forward for alternatives development and evaluation. After the identification and screening steps are completed, the retained technologies (and representative process options) will be assembled in the FS into a focused set of Site-wide alternatives in accordance with CERCLA guidance. The evaluation described in this section includes consideration of all technologies that may be appropriate to any portion of the Site. Some GRAs or technologies, such as removal, may have limited applicability to the Site but are carried forward into the development of remedial alternatives because of the potential use of these technologies for part of a remedy for a portion of the Site. Notes about the applicability of the technologies are included in the screening discussions that follow.

The technology screening process below is based on the guidance provided in the *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (USEPA 1988) and the *Code of Federal Regulations* [CFR], Title 40, Part 300.430(e)(7). The following technology evaluations provide, to the extent practicable, an appropriate level of detail to allow a balanced screening level assessment. The evaluations are based on an appropriate level of reasoning, experience, and professional judgment for conceptual-level studies. A more rigorous approach to remedial alternatives evaluation, which will include consideration of all of the criteria specified in 40 CFR 300.430(e)(9) for the detailed evaluation of remedial alternatives, will be performed, where appropriate, during the FS for those alternatives that include the technologies carried forward.

4.1.1 Implementability

This evaluation criterion is based on two aspects of a given technology's feasibility: 1) technological and 2) administrative. Specifically, technological feasibility refers to both the short-term (i.e., construction, operation, and completion of the remedial action) and long-term (i.e., operations and maintenance, replacement, and monitoring post-remedial action completion) aspects of an alternative and considers the availability of the equipment and specially trained personnel required to implement a remedy, as well as physical characteristics of the Site that may impede implementation of a particular technology. Administrative feasibility refers to the necessary agency coordination and ARAR compliance prior to on-Site execution of an alternative.

4.1.2 Effectiveness

The evaluation of the effectiveness of a given technology focuses on its ability to reduce the toxicity, mobility, or volume of a chemical within a specified matrix; all of these characteristics point to the ability of a technology to effectively minimize or eliminate the risk associated with a particular chemical. The effectiveness evaluation considers potential short-term impacts (potential to temporarily increase risks during implementation) and long-term aspects (the durability of the remedy and the amount of future activity that would be required to maintain the long-term effectiveness of the remedy). Short-term effectiveness also includes consideration of the time required for the remedy to achieve the anticipated degree of risk reduction.

4.1.3 Cost

An assessment of the construction or implementation costs associated with a particular alternative is also required as part of the screening evaluation. Cost is used as a coarse screen for eliminating remedial alternatives that are much more expensive without offering commensurately greater effectiveness. Per the NCP (40 CFR 300.430(e)(7), "[c]osts that are grossly excessive compared to the overall effectiveness of alternatives may be considered as one of several factors used to eliminate alternatives." The referenced guidance (USEPA 1988) indicates that adequate information for each screened technology is necessary to perform "comparative estimates" that can be carried forward for further evaluation in the subsequent detailed analyses in the FS; therefore, only a certain degree of alternative refinement is necessary at this stage of the evaluation. Although the cost-estimating guidance (USEPA 2000) refers to "order-of-magnitude" estimates in the screening stage, the "expected cost estimate accuracy" in the screening of remedial alternatives is -50 percent/+100 percent. Cost estimates were developed considering the major elements of implementing each technology at the Site. These major elements, as well as other assumed values, are identified in the respective cost discussions for each technology.

Cost assessments for the presented technologies are provided on a unit price basis, providing a simplified metric for technology evaluation. During the FS, additional considerations, such as the cost of long-term operations, monitoring, and maintenance (OMM) need to be considered in the full evaluation of each alternative. Some technologies have relatively low OMM costs (e.g., removal), while others (e.g., containment) will include costs for monitoring and maintenance activities following construction of the remedy as determined appropriate.

4.2 Critical Site Restrictions

As discussed in Section 3.4, different categories of SMAs are proposed for the Site to facilitate remedial alternatives screening in the FS. Existing Site conditions were used to define these areas, and in certain instances, these conditions could affect one or more of the criteria listed above. For example, areas with limited access that require specialized equipment for implementation of a certain technology may have higher costs than those areas with unrestricted access. The following sections provide a discussion of restrictions imposed by on-Site conditions within the SMAs.

4.2.1 Structural Restrictions

Areas within the Site that have fixed structures may preclude the successful implementation of certain remedial design technologies listed in Table 4-1. Examples of structures that may interfere with implementation of remedial actions include:

- Immovable fixed bridge and utility crossings
- Hard armored slopes
- Existing shoreline retaining structures
- Active drainage outfall structures
- Proximity to plant process equipment (i.e., flares, etc.)

Some of these structures are active and have daily use. The upstream portion of the channel has hard armored slopes that protect these over-steepened areas from erosion and undermining. At several locations, over-channel pipe crossings are present. Twin culverts are present at the upstream end of the Site that serves as the primary connection between the Deer Park municipal drainage and the Site. A thorough evaluation of these areas, which includes coordination with facility owners and operators, must be made prior to final remedy selection, as implementation of certain remedial actions would likely disrupt on-Site operations. In addition, removal GRAs could have fatal-flaw issues related to structures as removal of sediment can reduce the structural capacity of pile foundations. The extent to which this could be an issue is unknown and will be evaluated in more detail during the FS, as appropriate, to the final alternatives considered.

4.2.2 Use, Habitat, and Water Depth Considerations Related to Remediation

The Site is an isolated waterway that functions primarily for industrial and municipal stormwater drainage purposes. Water depths are typically shallow; however, during large rain events the Site has been known to flood, which will be better controlled after construction of the detention basin. These areas provide habitat for fish and invertebrate species described in Section 2.2.4. Table 4-3 provides a description of the use, habitat, and water depth considerations for each of the SMAs.

Table 4-3
SMA Critical Site Restrictions

SMA Name	Use, Habitat, and Water Depth Considerations Related to Remediation
Nearshore (NS)	Likely the only vessels that are capable of accessing the majority of the NS areas are shallow draft barges, which would be limited to periods of higher water. As discussed above, this SMA includes the portions of the Site where the water depth is 2 feet and shallower and/or are within 50 feet of the shoreline. This offset distance is assumed based on the reach of a long-stick excavator. Landside and waterside access to this SMA is restricted to approved personnel. Remedial action conducted for impacted sediments in this SMA will require coordination with the adjacent property owner(s). Habitat along the NS area of the Site is not extensive. Species type and diversity is dependent on the water depth and existing shoreline conditions. Significant impacts are not expected as a result of remedial action at the Site.
Structures (ST)	Fixed structures associated with the facilities located on the eastern and western banks of the Site are accessed on a daily basis. Access is critical to the operation of the facilities and is rarely discontinued for any significant time period.

SMA Name	Use, Habitat, and Water Depth Considerations Related to Remediation
	Pipelines and bridges transect the Site in several locations (above and below grade). Coordination with the owner(s) will be necessary to establish required offsets for work conducted as part of remedial action for the Site. If any removal of sediments is required, specific considerations should be made for the stability of the structures during construction and post-implementation. It is likely impracticable that any of these structures providing conveyance for either workers or materials can be removed or realigned to accommodate remedial action efforts. Waterside equipment necessary for remedial action must be evaluated to assess the maximum and minimum overhead allowances necessary to access the Site. Permitted outfalls from adjacent facilities also terminate within the Site. It is likely that none of these structures can be altered to restrict or divert flow. Construction activities at the Site will likely require similar offset distances established by the owner(s) for each of the outfalls in the affected area. No habitat or water depth considerations for this SMA have been identified at this time.
Artificial Banks (AB)	This SMA is defined by the gunite-lined reach of the Site. This portion of the Site stretches from the upper boundary of the Site, defined by the two concrete culverts that extend upstream (southward) under SH 225, to the railroad crossing near Patrick Bayou Station 80. The total length of this reach is approximately 1,800 feet. The side slopes in this area are constructed with concrete. Bottom portions of the AB are earthen mixed with hard substrate in many areas. Landside and waterside access to this SMA is restricted to approved personnel and is limited due to safety considerations and existing structures that are adjacent to or that transect the Site. Remedial action conducted for impacted sediments in this SMA will require coordination with the property owner(s) and a full understanding of all overhead, surface, and below grade utilities and existing/planned structures prior to implementation. No habitat considerations for this SMA have been identified at this time.
Open-Water (OW)	Recreational boating is not allowed in the OW SMA. Access to this SMA is restricted to approved personnel. Remedial action conducted for impacted sediments in this SMA will require coordination with the adjacent property owner(s). Typical water depths across these areas of the Site are approximately 3 feet, and daily tidal fluctuation is 1.5 feet or less. The Site receives storm water runoff; during

SMA Name	Use, Habitat, and Water Depth Considerations Related to Remediation
	moderate and heavy precipitation events the flow is substantially increased. Remedial action in this SMA should consider potential impacts during precipitation events. Species type and diversity is dependent on the water depth and existing substrate conditions. Significant impacts are not expected as a result of remedial action at the Site.

4.3 Remedial Technologies

The following section describes remedial technologies that may be appropriate for the Site, discusses potential implementability, effectiveness, and costs associated with each technology, and describes whether a technology will be carried forward for consideration in the FS.

4.3.1 Institutional Controls

Institutional controls are administrative and legal controls that are used to limit human exposure to chemicals or to protect the integrity of a remedy. The National Contingency Plan (NCP, i.e., the regulations that guide Superfund response actions [codified at 40 CFR Part 300]), contains a preference for the use of engineered remedial actions that treat, remove, or contain chemically impacted materials to the extent that such actions are cost effective.

Institutional controls are generally used in conjunction with engineered controls where risks to human health have been identified. The two major types of institutional controls considered are proprietary controls and informational devices.

Proprietary controls may include:

- Waterway use restrictions and maintenance agreements
- Access and property use restrictions

Informational devices may include:

- Monitoring and notification of waterway users

- Seafood consumption advisories, public outreach, and education
- Enforcement tools
- Site registry

The Site has a variety of these controls already in place because of the industrial setting it lies within including waterway use restrictions for the HSC; maintenance agreements; access and property use restrictions; Homeland Security requirements; monitoring and notification of waterway uses in the HSC; seafood consumption advisories in the HSC and Galveston Bay; and associated public outreach and education.

Institutional controls are potentially applicable to all areas of the Site.

4.3.1.1 Implementability

Institutional controls are technically implementable. The administration of institutional controls would need to be further coordinated with stakeholder groups, such as Harris County, the Port of Houston Authority (POHA), and regulatory agencies.

When using institutional controls alone, implementability is often considered to have a moderate rank at many CERCLA sites, as there may be administrative hurdles to overcome to enact certain use restrictions. However, there is a long history of successfully implementing a variety of institutional controls at the Site, and implementability of using these controls is considered to rank high for this Site.

4.3.1.2 Effectiveness

Institutional controls have been widely used to effectively protect human health from certain exposure pathways. Institutional controls are often used in conjunction with remedial technologies that isolate chemically impacted sediments in places or in circumstances where potential exposure to chemicals is expected to persist (USEPA 1997). Institutional controls do not reduce the toxicity, mobility, or volume of chemicals but they can be used to mitigate risk. The institutional controls already in place at the Site are very effective in reducing human exposure to Site COPCs; therefore, these controls are assigned a high ranking because of their demonstrated effectiveness.

4.3.1.3 Cost

The cost of implementing institutional controls is low compared to the cost of implementing engineering controls. Costs are primarily related to administrative and legal activities, community education and engagement, construction and maintenance of fencing and warning signs, as well as potential long-term monitoring costs.

Estimated costs related to administrative, legal, and community engagement have not been calculated at this time.

4.3.1.4 Summary

Institutional controls are retained as a remedial technology (Table 4-4).

Table 4-4
Institutional Controls Screening Summary

GRA	Technology Type	Process Option	Implementability	Effectiveness	Cost	Screening Decision
Institutional Controls	Administrative and Legal Controls	Access and property use restrictions	High	High	Low	Retained for all areas
		Informational devices (e.g., signage and fish consumption advisories)	High	High	Low	Retained for all areas

4.3.2 Monitored Natural Recovery and Enhanced Monitored Natural Recovery

As outlined in USEPA's *Sediment Remediation Guidance* (USEPA 2005), MNR is a remedy for contaminated sediment that typically uses ongoing, naturally occurring processes to contain, degrade, or reduce the bioavailability or toxicity of chemicals in sediment and associated surface water. MNR may rely on a wide range of naturally occurring processes to reduce risk to human and ecological receptors. These processes may include: 1) physical; 2) biological; and 3) chemical mechanisms that act together to reduce the risk posed by the chemicals. Depending on the chemicals and the environment, this risk reduction may occur in a number of different ways, including destruction (degradation or transformation) of COCs to less toxic chemicals, reduced mobility of COCs, burial, or dispersion.

A variation of MNR is EMNR where one of the driving mechanisms (such as burial) is accelerated. A common method of EMNR is the placement of a thin layer of clean sediment over the affected area.

Forms of MNR are potentially applicable to all areas of the Site. Natural recovery processes that rely on deposition of fresh sediment or long-term stability of sediment may be limited in applicability to more depositional areas as noted in the following discussions.

4.3.2.1 Implementability

MNR and EMNR are technically and administratively implementable for the Site. Areas of Patrick Bayou are sufficiently depositional (Anchor QEA 2011) such that surface concentrations of COPCs are expected to be reduced by one-half in fewer than 10 years. As discussed in Section 2.1.2, the proposed detention basin may increase sediment deposition and enhance the effectiveness of MNR, although modeling has not been performed to assess the potential effect of the detention basin. The potential exposure pathway would be blocked if clean sediment is deposited over chemically impacted materials. For an MNR remedy, the activities required would be the preparation of a monitoring work plan and the implementation of monitoring and reporting. None of these activities would be technically difficult to implement and the only administrative requirement would be the approval of the work plan. For an EMNR remedy, additional activity, such as the placement of clean sediment, would be required, in addition to work plan development and monitoring. This physical activity would use well-demonstrated and readily available equipment and materials, so there are limited impediments to implementation, primarily associated with Site access, which is restricted by adjacent facilities and infrastructure in some areas of the Site. Both MNR and EMNR are highly implementable in accessible portions of the Site.

4.3.2.2 Effectiveness

The *Sediment Transport Modeling Report* (Anchor QEA 2011) describes the evaluation of sediment movement through the Site. The evaluation found that the energy system of

Patrick Bayou below the gunite-lined channel results in an overall deposition of sediment. The amount of deposition varies for different areas of the Site and periods of deposition are interspersed with periods of erosion, but the evaluation concluded that net sedimentation rates are as high as 2 cm/year. The evaluation also considered the degree of erosion during high-flow events. The model found that net erosion occurs in approximately 65 percent of the bed area during a 100-year high-flow event, and that erosion in such an event is less than 6 cm in most areas for this event. The evaluation did not include modeling of chemical fate and transport, but the principal constituents associated with risk at the Site (PCB congeners) tend to adsorb strongly to sediment, so concentrations of these constituents in the biologically active shallow sediment are expected to decrease with the deposition of relatively clean sediment. Natural recovery and enhanced natural recovery are expected to be highly effective mechanisms for reducing risk at the Site and would provide the benefit of retaining the existing benthic community. The effectiveness of EMNR and MNR would need to be evaluated in more detail in those SMAs that include the -NE_{100} modifier in their designation. The detailed evaluation of effectiveness in the FS will need to consider chemical transport independent of the sediment transport to assess the time that would be required to meet RALs and the long-term concentration trends that could affect risk.

One factor that must be considered in the future evaluation of this remedial technology is the construction of the stormwater retention basin by the City of Deer Park on the southeast side of SH 225. This retention basin will minimize surges/system flashes when erosion of surface sediments would likely occur and may affect the overall sedimentation rate at the Site.

4.3.2.3 Cost

MNR and EMNR each involve monitoring the shallow sediment to demonstrate a reduction in the concentration of Site COCs over time. Sediment samples representative of initial conditions would be collected in areas where MNR or EMNR remedial action is chosen as the preferred alternative. The samples would be analyzed for Site-specific COCs. Subsequent monitoring would involve collecting surface grab samples in essentially the same locations, using the same collection methods, and analyzing the samples for the same Site-specific COCs. Monitoring schedules can vary but would typically include collecting samples annually for five years and then once every five years thereafter for a total of 30 years (for a total of ten rounds of sampling); the sampling schedule could be modified with USEPA approval if the results of the monitoring indicated that more or less monitoring was needed or if some disturbance of the sediment was suspected due to a change in flow conditions or some other event.

This technology may also involve implementing administrative controls, such as posting signs advising against disturbing sediment in the impacted area. The implementation cost associated with EMNR assumes installation of a 6-inch sediment cover. The cost estimate for EMNR includes costs for materials, equipment, and labor to place the sediment cover and may range from approximately $70,000 to $100,000 per acre. The actual cost of EMNR would depend on the source of EMNR material and the thickness of the cover materials. The relative cost of MNR or EMNR compared to other active remedial technologies would be low, and low to moderate, respectively.

4.3.2.4 Summary

MNR and EMNR are retained as a remedial technology (Table 4-5) potentially applicable to areas of the Site with high NSR. The FS will assess the degree and spatial extent to which MNR or EMNR can be expected to be a suitable remedy that meets the RAOs. The evaluation will involve modeling chemical fate and transport within and around the Site to determine how quickly and to what degree chemical concentrations in surface sediments may change and the degree to which human and ecological exposure to Site-specific COCs can be expected to decrease over time. This information may include (but is not limited to) evaluations of sediment samples collected over time and evaluations of concentration profiles in cores. The timeframes for acceptable MNR or EMNR will be set to be consistent with appropriate guidance.

Table 4-5
MNR and EMNR Screening Summary

GRA	Technology Type	Process Option	Implementability	Effectiveness	Cost	Screening Decision
Natural Recovery	Monitored Natural Recovery	Natural Sedimentation	High	High[1]	Low	Retained for specific areas[1]
		Placement of thin layer of clean cover	High	High[1]	Low to Moderate	Retained for specific areas[1]

Note:
[1] The high effectiveness assessment applies to stable areas of the Site with a high NSR.

4.3.3 In-situ Containment (Capping)

In-situ containment refers to the placement of an engineered subaqueous cap on top of chemically impacted sediment that will remain in place. A cap would be designed to effectively contain and isolate such sediments from the biologically active surface zone. As described in *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (USEPA 2005), in-situ caps can quickly reduce exposure to chemicals and typically require less infrastructure than ex-situ technologies (e.g., dredging, dewatering, treatment, and disposal). Since capping leaves contaminated sediments in place, long-term monitoring is typically a component of in-situ containment to verify that the cap is stable (i.e., not damaged) and continues to effectively isolate chemicals, or sufficiently attenuate chemical mobility through the cap (USEPA 2005).

In-situ caps isolate chemically impacted sediments from the environment by use of natural (e.g., sand) or constructed (e.g., geosynthetic layers or concrete) products. Depending on the proposed remedial design for a site, a cap can consist of a single sediment layer to isolate chemicals or can be designed as a multi-layered system consisting of a combination of sediment, geosynthetic, and armor layers.

Detailed guidance manuals for in-situ containment for chemically impacted sediments have been developed by the U.S. Army Corps of Engineers (USACE) and USEPA (Palermo et al.

1998; USEPA 1998). The screening intends to provide a general overview of in-situ containment technology and refers the reader to USACE and USEPA guidance manuals for detailed information on cap design for chemically impacted sediments.

The main component of an in-situ containment design is the chemical isolation layer. This portion of the cap reduces the flux of the solids and dissolved chemicals to the overlying water column to acceptable levels. The chemical isolation component is typically made of naturally occurring sands or gravels. Additives, such as organoclay or other products (e.g., AquaBlok), have been used to help sequester more mobile dissolved chemicals; this application is discussed in the following section. For sites with lower erosion potential, typically sand, or sand and gravel substrate, can be used for a cap. For higher flow conditions, or where a thinner cap may be necessary to maintain water depth, an engineered "armor-form" material could be used. Because of the known flooding issues during high precipitation events within and upstream of the Site, thinner cap sections are preferred so as to maintain maximum flow and drainage capacity. In areas of the Site with particularly constrained flow, limited sediment removal might be required before placing a cap to avoid upstream flooding. A hydrologic analysis would be required to evaluate the need for sediment removal. For the purposes of this screening, a prospective pumped concrete and geotextile Articulated Concrete Block Mat (ACBM) cap is evaluated for the cost assessment, although a more traditional aggregate cap may be amenable for consideration in specific areas of the Site and will be retained for more detailed consideration in the FS. Where ACBM is used, an empty geotextile armor-form is initially placed at the mudline, and concrete is pumped into the form to create the cap. Based on further design considerations to be presented in the FS, this concept may be adjusted based on the characteristics of a particular SMA. Other components may be added, if necessary, to reduce the permeability of the cap, or to reduce chemical mobility through the cap. Alternatives to in-situ formed ACBM, such as precast ACBM, may also be considered as optional cap materials.

Placing an ACBM cap in a controlled fashion is relatively easy to do under suitable on-Site conditions (e.g., low currents, calm water state, lack of physical restrictions, and relatively flat bottoms), and can be accomplished with a variety of equipment such as shallow water skiffs and winch and anchor blocks deployed from the upland. ACBM has been successfully deployed under higher flow conditions; however, control of placement is more difficult because the geotextile armor-form can be moved by the current during initial deployment.

4.3.3.1 Implementability

In-situ containment methods can be successfully implemented at the Site; however, Site access is limited in some areas due to adjacent infrastructure and utilities. To implement a containment remedy, specialty equipment may need to be used, or temporary access may need to be built in order to facilitate construction. The construction of in-situ containment caps is subject to short-term technological feasibility issues as well. Specifically, since a portion or all of the construction activities will take place waterside, the on-Site hydrodynamic conditions are a significant factor. Periods of high flow could impact the installation of the ACBM cap causing movement of the empty armor-form prior to concrete pumping. This can be mitigated by monitoring flow conditions during construction and adjusting procedures accordingly.

Low-permeability caps using geomembrane are significantly more difficult to construct than conventional caps, since working with either liners require specialized equipment and/or methods to place. Geomembrane caps have not been proven to be technically implementable for sites with deep water depths, accessibility issues, or higher flow conditions. The use of materials like AquaBlok has been demonstrated in similar site conditions. However, the presence of brackish water may affect the effectiveness of these types of materials.

The long-term technological feasibility of in-situ containment is supported by operations, monitoring, and maintenance actions that are developed during the remedial design. Such plans present criteria that trigger additional monitoring and repairs, as needed, for the areas where caps have been installed.

Administrative feasibility of in-situ containment is dependent on the material and equipment necessary for installation and potential access issues prior to and resulting from implementation. In-situ containment caps consist of readily available materials and can be installed with conventional construction equipment where access is good, although technologies like ACBM are ideally deployed by an experienced contractor. Installation of an ACBM cap around and under existing waterside structures (ST type SMAs) within the Site can be accomplished by hand deploying the armor-form geotextile prior to filling with concrete.

Although completed caps will generally compress underlying sediments, the water depth in areas that receive caps will potentially be altered. Changes in the water depth could affect flood stage for areas within the Site. Modeling would be conducted during the FS to evaluate the resultant hydrodynamics for post-remedy conditions at the Site.

4.3.3.2 Effectiveness

In-situ containment methods have been demonstrated in previous applications to effectively sequester COCs, particularly for highly sorbed chemicals, such as PCBs. Depending on the chemical, the addition of a reactive component (e.g., activated carbon [AC]) could provide additional reduction in mobility.

Short-term effectiveness of this technology relies on the initial coverage of the chemically impacted material immediately following installation of the cap. Once the isolation cap layer has been installed, the chemicals are effectively sequestered. Benthos living in chemically impacted sediments beneath the capped area may be temporarily lost, but they will quickly recolonize the surface of the cap, likely within months of cap placement given sufficient sediment deposition. Since capping disturbs relatively little in-situ chemically impacted sediment, this technology is considered to have few other environmental impacts during construction.

The long-term effectiveness of in-situ containment methods depends on the stability of the cap components. An ACBM cap incorporates a concrete surface that is considered highly stable. Where aggregate caps are considered, an armor surface component such as rock may need to be considered, particularly in those SMAs that have the –NE modifier in their designation, where armoring would need to be evaluated in greater detail in the FS. Cap design should consider the potential for migration of underlying chemical through the cap to surface water. Installation of a sediment cap would eliminate the existing benthic habitat in the short-term. Habitat would be re-established after a sufficient layer of new sediment was deposited, and habitat layers are sometimes included in the construction of sediment caps.

4.3.3.3 Cost

As discussed above, an ACBM cap was assumed for the development of an initial order-of-magnitude cost range. An un-amended ACBM cap is estimated to cost $650,000 to $900,000 per acre. The ACBM cost estimate includes the costs of the panels of the geotextile forms, the concrete grout, and the equipment and labor to construct the cap. The cost for adding amendments to cap layers is discussed in further detail in Section 4.3.4.3. Conventional aggregate caps are considerably less expensive than ACBM caps in terms of material costs; however, when accounting for the cost of dredging to maintain water depth for a conventional cap, ACBM caps can be significantly less expensive as an overall remedy. The major cost elements of an aggregate cap are the materials (assumed to be a sand isolation layer and a coarser stone armor layer) and the labor and equipment to place the cap.

4.3.3.4 Summary

In-situ containment through single- and multi-layer cap systems is a well-demonstrated technology for sequestering COCs. This remedial design method can be successfully implemented in both shallow and deeper water portions of the Site. However, the resultant alterations in water depth may impact flood conditions in the surrounding area if cap thicknesses are significant. Limited removal of sediment prior to capping may be required in areas of constrained flow to maintain the hydraulic capacity of the channel. For planning purposes, the screening assumes that the prospective cap would use a concrete filled geotextile known as ACBM, so as to minimize the impact on flood storage capacity within the Site, with limited application of more conventional aggregate caps, as appropriate, for certain areas of the Site that may be identified in the FS. In-situ capping technology has been retained for further evaluation in the FS (Table 4-6). This technology is potentially applicable to the entire Site with the reservations noted in this section.

Table 4-6
In-situ Containment Screening Summary

GRA	Technology Type	Process Option	Implementability	Effectiveness	Cost	Screening Decision
In-situ Containment	Capping	ACBM	High	High	High	Retained
		Aggregate and Natural Materials	Limited[1]	High	Moderate to High[2]	Retained

Notes:
1. Conventional aggregate caps tend to be thicker than ACBM and have a greater impact on flood storage within the Site. Their application as a remedial technology within the Site is expected to be more limited, and will be evaluated in greater detail in the FS.
2. The initial cost of aggregate and natural material caps is considerably less than ACBM caps; however, the cost of dredging to maintain water depth for a conventional cap would significantly increase overall remedy costs.

4.3.4 In-situ Treatment

Treatment technologies were reviewed for potential applicability to remedial action by considering the chemical properties of the Site-specific COCs and the physical constraints of the Site. The results of the treatment technology review are presented in Appendix A, and the screening of in-situ treatment technologies is summarized in this section.

In general, in-situ sediment treatment technologies include immobilization of the COCs with the addition of sequestering agents (e.g., AC), biological or chemical degradation, other forms of immobilization, and other potentially appropriate treatment technologies to reduce the toxicity, mobility, or volume of sediment chemicals while leaving sediments in place.

As discussed in Appendix A, adsorbent amendments may be added to the sediment in-situ to effectively reduce the mobility and bioavailability of the Site-specific COCs. Adsorbent materials may also be added to cap fill, as discussed in Section 4.3.3. The primary exposure medium of concern is the shallow sediment, within 10 cm of the sediment-water interface. The consideration of in-situ treatment technologies is focused on the top 10 cm of sediment within the Site.

4.3.4.1 Implementability

Technical feasibility of in-situ treatment is moderate to high for the target sediment, within 10 cm of the sediment-water interface. The implementation of in-situ treatment is subject to short-term technology feasibility issues, similar to those presented for in-situ containment. Specifically, since the primary construction activities would take place in the water, the on-Site hydrodynamic conditions would be a significant factor for in-situ treatment. Periods of high flow could impact the installation of adsorbent amendments by causing unwanted transport of lighter-weight materials (e.g., bulk AC) during placement. This can be mitigated by monitoring flow conditions during construction and adjusting procedures accordingly. Certain construction methods have been developed for the direct application of amendments to surface sediments via tilling or injection, which minimizes the interaction of the amendment and the surface water.

The technical feasibility of in-situ treatment is also driven by the availability of the material and equipment necessary for installation. Adsorbents range from proprietary materials that can be coated on aggregate to bulk materials that can be blended or injected into the sediment; they can also be added as a component to geotextile mat layers or mixed with a thin layer of sand, which can provide additional uniformity to a remedial design, depending on site conditions. Amendment materials may be placed using standard construction equipment. The addition of adsorptive amendments can be successfully implemented in both shallow and deep water portions of the Site. SMAs that experience net sedimentation, but may not meet the required remediation timeline by MNR alone, are candidate areas for in-situ treatment. Therefore, in-situ treatment has been retained for further evaluation in the FS (Table 4-7).

Administrative feasibility of in-situ treatment should be moderate to high. In-situ treatment would take place completely on-Site and would be exempt from permitting under the CERCLA exclusion. Coordination with local authorities would be necessary because of the addition of material to a floodway, but in-situ treatment would not impede drainage unless significant armoring is required to protect the amended sediment from erosive forces. Access to the Site is available through the properties of the JDG members. While remedial activities would need to be coordinated with production activities, access agreements from third parties would not be needed.

4.3.4.2 Effectiveness

Organoclay and AC have both been demonstrated to be effective and reliable for passively removing organic contaminants from water. AC is particularly effective for removing trace amounts of organic compounds from water. Organoclay is very effective for removing nonaqueous-phase liquids from water and is also effective for removing dissolved contaminants, although it may be less effective than AC for removing already very low concentrations of organic contaminants from water (Reible et al. 2008).

The effectiveness of any adsorptive material relies on its ability to remain in place. An armor layer may be necessary to protect sediment treated with adsorptive amendments from periodic erosive forces associated with stormwater runoff and, in SMAs adjacent to the HSC, erosive forces induced by tidal fluctuations and vessel-generated waves. Organoclay and AC adsorbent amendments are given a high effectiveness rating for application at the Site.

4.3.4.3 Cost

The basis for the development of estimated unit costs for treatment with adsorbent amendments is described in Appendix A. The costs for in-situ treatment include the cost of amendments plus the cost of the equipment and labor to mix the amendment with the sediment. The cost to add adsorbent amendments to the sediment ranges from $37,500 to $72,500 per acre for AC and organoclay, respectively, but a cap would need to be added to protect the treated sediment from erosion. The estimated additional cost of the armored cap would range from $210,000 per acre for a granular cap to $900,000 per acre for an ACBM cap. For an amended cap, the cost elements include the amendment, the cap materials, and the labor and equipment to mix the amendment with the aggregate and to place the amended cap material.

4.3.4.4 Summary

In-situ treatment using adsorptive amendments is a well-demonstrated technology to effectively control the mobility of organic contaminants, disrupting the exposure pathway between affected sediments and potential receptors. In-situ treatment would not increase the ability of the sediment to resist erosive forces that could disperse shallow, treated sediment and expose deeper, untreated sediment. Therefore, this technology would likely need to be used in conjunction with an isolation cap. The evaluation of in-situ treatment is summarized in Table 4-7.

Table 4-7
In-situ Treatment Screening Summary

GRA	Technology Type	Process Option	Implementability	Effectiveness	Cost	Screening Decision
In-situ Treatment	Physical-Immobilization	Adsorptive Amendments	Moderate to High	High[1]	Moderate to High	Retained

Notes:
[1] The high effectiveness assessment applies to shallow sediment (within approximately 10 cm of the sediment-water interface) in stable areas of the Site with a high NSR.

4.3.5 Removal

The two most common technologies for removing chemically impacted sediment from a water body are excavation and dredging (USEPA 2005). In this context, excavation refers to removal activities that are performed in dry conditions, after water has been diverted or drained from the removal area; dredging refers to removal activities that are performed while the sediment remains submerged. Both removal technologies, along with several associated process options, are discussed in more detail in this section.

Chemically impacted sediment removal can result in the least uncertainty with respect to the effectiveness of chemical mass reduction of a remedy (USEPA 2005) at sites with relatively shallow contamination and decreasing concentrations with depth. Removal can provide increased flexibility in future uses of the waterway and may be used in conjunction with capping, where necessary, to maintain the hydraulic capacity of a waterway. However, removal results in greater short-term environmental impacts from chemically impacted sediment loss and resuspension/redistribution than other remedial technologies. Removal can result in short-term water quality impacts from dredging releases that can increase fish and shellfish tissue concentrations (Bridges et al. 2010), and there are often post-dredging surface contamination issues associated with residual materials on the surface of the remediated area (National Research Council [NRC] 2007). Chemically impacted sediment removal evaluations should also consider Site restrictions associated with existing structures that can limit the ability to remove all chemically impacted sediment within the waterway (USEPA 2005).

Chemically impacted sediment that has been removed requires processing that may include dewatering, offloading, transport, treatment, and disposal, each of which involves additional costs, the potential for further releases, and the potential for future liabilities associated with the disposal facility.

This screening intends to provide a general overview of removal technologies. Detailed guidance manuals for environmental dredging of chemically impacted sediment have been developed by the USACE (2008), the USEPA (2005), and the NRC (2007); the reader is referred to those documents for detailed information on environmental dredging for chemically impacted sediment.

4.3.5.1 Dry Excavation

Sediment excavation involves the use of excavators, backhoes, and other conventional earth moving equipment to remove contaminated sediment after water has been diverted or drained from the removal area (i.e., "in the dry" removal).

Diversion of water from the excavation area can be facilitated through the installation of temporary cofferdams, sheetpiling, or other water management structures, followed by removal of surface water within the excavation area, which generally occurs via pumping. Following dewatering of the area, equipment can be positioned on the sediment bed within the excavation area or immediately adjacent to the dewatered excavation area.

Dry excavation in river systems has significant limitations that have been well documented (USEPA 2005; USACE 2008; Bridges et al. 2010; Connolly et al. 2007), and it is not considered feasible for significant portions of the Site because isolating an area for dry excavation would serve to further limit the hydraulic capacity of the Site. There may be limited areas near open shorelines where dry excavation potentially could be used; depending on access for staging equipment on the shoreline, but for purposes of this screening, dry excavation will not be evaluated further. However, it will be retained and addressed in more detail in the FS as a potential removal technology that may have limited application within the Site.

4.3.5.2 Dredging

Dredging is a method of removing sediments without water diversion or draining (i.e., "in the wet" removal). Hydraulic or mechanical dredging is generally accomplished using floating equipment.

Regardless of the dredging method and use of dredging Best Management Practices (BMPs), short-term water quality impacts and residual contamination post-dredging are inherent to the dredging process and require mitigation planning (USACE 2008). Short-term water quality impacts from dredging releases can lead to increased concentrations of COCs in fish and shellfish tissue. Dredging BMPs that are typically employed to help comply with water quality criteria include: operational controls, engineered controls such as barriers and silt curtains, and specialized dredging equipment (such as closed buckets), and water quality monitoring.

All dredging projects result in some degree of resuspension, release, and residuals/redistribution (NRC 2007). Residual contamination is defined as both chemically impacted sediment that remains un-dredged due to the inability to be 100 percent accurate in delineating and removing all of the chemically impacted sediment, or chemically impacted sediment that was resuspended during dredging and that could not be fully captured (i.e., due to removal equipment limitations in preventing loss of sediment during the action of dredging), potentially impacting previously unimpacted areas. The need to address residual contamination post-dredging depends upon the concentrations and thicknesses of residuals remaining. However, empirical data from numerous sediment remediation projects indicate that residual contamination is a common occurrence and that sites with high concentrations are unlikely to achieve RALs with dredge technology alone (Patmont and Palermo 2007; NRC 2007).

Placing a thin clean sediment cover as a final step in the remediation process has been successfully used to manage residuals to achieve cleanup levels on the surface post-construction. For purposes of this screening, the dredging alternative will assume that a residuals management cover would be placed in all areas where dredging occurs. In concept, this would entail placement of a nominal 6-inch thickness of clean sand over areas that require residuals management.

4.3.5.2.1 Mechanical Dredging

Mechanical dredges have been used in the HSC and nearby waterways for sediment remediation projects. A barge-mounted crane can use different types of buckets or attachments to dredge. Mechanical dredges can work in difficult-to-access areas and are relatively easy to reposition, thus reducing the potential impact to other waterway uses. However, mechanical dredges cannot effectively work under low clearance overwater structures to remove sediment. Mechanical dredges require several feet of water to provide sufficient draft for the floating equipment, which may limit their applicability to certain areas of the Site.

Mechanical dredges are designed to remove sediment at or near in-situ density (USEPA 2005), although some amount of excess water is typically entrained in the dredge bucket as it closes and is lifted up through the water column. The quantity of water generated using mechanical dredging is orders-of-magnitude less than the quantity of water generated with hydraulic dredging. Mechanical dredges can effectively remove consolidated sediment, debris, and other materials such as piling and riprap. Following removal, the mechanically dredged sediment typically requires processing. A typical "treatment or process train" for mechanical dredging (assuming landfill disposal) is shown below:

1. Dredge chemically impacted sediment
2. Place chemically impacted sediment in a haul barge
3. Passively dewater sediment on the barge
4. Transport chemically impacted sediment to either an on-Site or off-Site offloading/staging area
5. Offload sediment to a stockpile area for either passive or active dewatering
   - Dewatering methods may include working the sediment with standard earthmoving equipment, adding amendments, using filter or belt presses, using hydrocyclones
6. Treat effluent water from the stockpile and discharge to receiving waters or approved publically owned treatment works (POTW)
7. Transport chemically impacted sediment over land by truck or rail or over water by barge
8. Dispose of chemically impacted sediment at a landfill facility

Mechanical dredging is considered feasible for open-water areas because of its ability to effectively remove consolidated sediment, debris, and other materials such as piling and riprap and its ability to easily relocate during construction, thus reducing the potential impact to other waterway uses. However, significant limitations associated with water depth and dewatering will dictate the selection of equipment and consideration of implementability of this technology.

4.3.5.2.2 Hydraulic Dredging

Hydraulic dredging typically involves using a cutterhead or similar equipment to remove sediments from the sediment bed in a sediment/water slurry. This slurry is pumped through the dredge and transported via pipeline to a processing or disposal facility. Hydraulic dredging has been implemented at many sites with chemically impacted sediments.

Relative to mechanical dredging, a significantly greater volume of water is entrained with the sediment slurry removed by the dredge and must be subsequently separated from the sediment solids and treated and discharged (USEPA 2005). The solids content of hydraulically dredged slurries typically averages about 5 to 10 percent by weight, but it can vary considerably depending on sediment characteristics (i.e., specific gravity, grain size, and moisture content) and the depth and thickness of the dredge cut. In general, hydraulic dredges cannot remove large rocks and debris.

The hydraulically dredged slurry can be transported via piping directly to a staging/processing area that is typically land based. The hydraulic transport pipeline is typically a floating pipeline, which can interfere with vessel navigation; however, this would not be an issue at the Site. The staging area is ideally in close proximity to the dredge area due to the difficulties in placing, operating, and maintaining long distances of pipeline and may require a large footprint depending on the dredging production rate, as well as options used to dewater, process, stockpile, transload, and transport the dredged sediment.

Dewatering of hydraulically dredged sediments is required prior to transport and disposal of the sediment. Hydraulically dredged sediments can be dewatered using passive or active methods; this typically requires use of a large area for passive settling basins or geotextile tubes, due to the relatively large volume of water added for slurry transport. Active dewatering methods may include filter or belt presses, hydrocyclones, or other methods; additives may be used to enhance dewatering by these methods. Water removed from the dredged slurry typically requires treatment prior to discharge.

4.3.5.3 Implementability

Dredging as a primary removal technology is considered to be technically implementable at the Site. Shallow water conditions and adjacent infrastructure and utilities could preclude dredging in areas of the Site that cannot be reached from the shoreline and that do not have enough water to support a barge. At least 30 percent of the Site may be inaccessible to dredging at normal water levels depending on the type of dredging equipment used[8], although temporary water-level controls may be used, if necessary, to facilitate dredging. Mechanical and hydraulic dredging, as primary process options, are technically implementable in most of the SMAs. Areas with fixed structures may require a separate remedial technology to protect the structure from undermining.

A dredge could be mobilized by water to the portion of the Site between the HSC and the bridge near Station PB-012. Dredging equipment would need to be mobilized to the rest of the Site by land because this bridge would block access from the HSC. Road access to the Site by large equipment may need to be improved to accommodate mobilization of the dredge and large support equipment, and based on existing infrastructure, there may be areas where large equipment cannot access. Dredge mobilization presents an implementability challenge that would need to be considered in additional detail during the FS and remedial design development.

For areas beneath the footprint of fixed structures, dredging using diver-assisted methods may be technically implementable, though this approach would present significant design and construction issues and would need to be evaluated in more detail during the FS. Dredging may need to be restricted adjacent to existing structures and slopes to avoid adversely impacting their stability. Table 4-3 summarizes critical Site restrictions within

[8] Approximately 70 percent of the Site has a water depth of 2 feet or greater at normal water level. Only about 25 percent of the Site has a water depth of 4 feet or greater at normal water level.

the Site SMAs that may impact the ability to fully remove all chemically impacted sediments.

From an administrative standpoint, removal by dredging is considered to be implementable. Removal by dredging has been accepted as a primary remedial technology on numerous contaminated sediment sites throughout the United States. Removal by dredging is considered to have a low to moderate rank for implementability, depending upon the various process options and due to critical Site restrictions that may limit its use in certain SMAs. In addition, residuals management strategies are expected to be necessary in conjunction with dredging.

4.3.5.4 Effectiveness

Removal has been proven to be an effective technology for achieving cleanup goals when used in combination with residuals management. Each process option discussed above can be effective given the appropriate Site conditions and must consider critical Site restrictions. Limited removal may be used in combination with another technology, such as capping, to develop a remedial alternative that is more effective than either technology on its own.

Removal technologies will not remove 100 percent of the chemically impacted sediment, leaving behind and allowing redistribution of chemically impacted residuals. The residual sediment limits the risk-reduction of the remedy, and consequently, reduces the effectiveness of the dredging remedy (NRC 2007). Research has shown that residual sediment remaining on the post-dredge surface (typically ranging from 2 to 11 percent of the chemically impacted sediment mass in the final production dredge pass) has been observed during most environmental dredging projects (USACE 2008). Management of potential post-removal residuals, either by placement of a residuals management cover (sand, gravel, or stone) or natural recovery, is commonly considered in the evaluation of excavation or dredging as a removal technology. For all removal technologies, effectiveness is improved by application of a residuals management cover, and this screening assumes that a residuals management cover would be placed in all dredged areas.

In addition to more general dredge residuals considerations, the subsurface profile of Site-specific COC concentrations increase with sediment depth, as discussed in Section 2.3.2.

Thus, the effectiveness of removal decreases with increasing depth, because the relative concentration of the post-dredge sediment surface, and the relative concentration of dredge residuals increase with depth. As a result, removal alternatives are considered to present greater risk compared to containment alternatives.

Dredging is considered to be a proven and reliable remedial technology and suitable for use for the Site, provided that dredge residuals and the risks associated with the depth profile of Site-specific COCs can be managed. Dredging does result in the release of chemicals during construction (i.e., dissolved or sorbed to suspended sediment particles) to the water column, and potential sediment transport will result in water quality impacts during dredging, even if the removal area is enclosed by turbidity control devices or other dredging BMPs are used. Whereas sediment turbidity impacts in the removal area can be minimized in certain applications through the use of BMPs, such as silt curtains, such BMPs have been demonstrated to be generally ineffective in areas with significant flows and generally ineffective in reducing the release of dissolved chemicals from any site. Therefore, dredging technology is considered to rank moderate for effectiveness.

4.3.5.5 Cost

Dry excavation is not feasible for the entire Site, but potentially may be used in some nearshore areas. The cost for removal by dredging, both hydraulic and mechanical, is high. Removal costs include the cost of dredging and also all of the ancillary construction elements that are part of the overall "treatment or process train." These ancillary construction elements may include 1) pre-dredge debris removal; 2) staging and stockpile area preparation; 3) dewatering; 4) water treatment; 5) sediment stabilization; and 6) environmental monitoring. The costs for transportation and disposal are discussed in Section 4.4.

Order-of-magnitude dredging costs were developed for this screening. The "treatment or process train" costs evaluated included mechanical dredging, monitoring, dewatering, and transloading; the total unit cost estimated was $75 to $90 per cubic yard (cy), not including off-Site transport and disposal. In the case of hydraulic dredging, the total cost of dredging is highly dependent on the volume of material being dredged, and the process option selected for dewatering the dredged sediments. Hydraulic dredging of small volumes of sediment has a relatively high unit cost due to the mobilization and setup of the hydraulic dredge and pipeline. For larger volumes, the efficiency of the hydraulic dredge results in lower unit costs. Based on recent local contractor estimates for smaller volumes of material at a nearby sediment site with significantly better access (30,000 cy or less), the unit cost could range from $60 to over $300 per cy or higher for hydraulic dredging.

4.3.5.6 Summary

Sediment removal by dry excavation (in limited nearshore areas) or by dredging is retained as a potential remedial technology (Table 4-8) with the above-noted limitations. Mechanical dredging would be limited to areas of deeper water. Limited sediment removal may be applicable in combination with another remedial technology, such as capping, to maintain the hydraulic capacity of the channel.

Table 4-8
Removal Options Screening Summary

GRA	Technology Type	Process Option	Implementability	Effectiveness	Cost	Screening Decision
Removal[1]	Dry Excavation	Soil Excavators	Low	Moderate[2]	High	Retained for limited nearshore areas
	Dredging	Mechanical Dredging	Moderate	Moderate[3]	High	Retained for areas of deeper water
		Hydraulic Dredging	Moderate	Moderate	High	Retained

Notes:
[1] Removal is potentially applicable in conjunction with other remedial technologies, such as in-situ containment, to maintain hydraulic capacity in constrained portions of the channel.
[2] The moderate effectiveness assessment applies to dry excavation in limited nearshore areas.
[3] The moderate effectiveness assessment applies to mechanical dredging in limited areas with sufficient water depth to support equipment.

4.4 Ex-situ Treatment and Disposal Technologies

4.4.1 Ex-situ Treatment Technologies

Ex-situ treatment may be required prior to transportation and disposal for sediment that is removed from the Site. As discussed in Section 4.3.5, sediment removal could be used as a principal technology for a remedial alternative or as a component of a containment remedial alternative. The *Patrick Bayou Treatment Technology Review* (Appendix A) presents the screening of treatment technologies for the Site. The retained ex-situ treatment technologies are summarized in the remainder of this section, and retained technologies will be developed into remedial alternatives in the FS. As noted in USEPA's *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites*, "…for the majority of sediment removed from Superfund sites, treatment is not conducted prior to disposal, generally because sediment sites often have widespread low-level contamination, which the NCP acknowledges is more difficult to treat" (USEPA 2005).

The ex-situ treatment technologies retained for further consideration, based on the evaluation in Appendix A, are immobilization by S/S and thermal treatment by incineration. The bases for not retaining sediment washing and thermal desorption are summarized in the following section.

4.4.1.1 Implementability

S/S is a well-demonstrated technology that has been used to immobilize chemicals and improve the handling characteristics of dredged sediment. Stabilized sediment can be disposed of off-Site or managed on-Site. Stabilized sediment that meets the requirements for leaching and bearing capacity may be used as fill. The equipment and materials for ex-situ S/S are readily available and may be set up at the Site if space is available or at an off-Site location, which would need to be acquired and permitted. Prior to transportation or disposal off-Site, sediment would need to be dewatered, which may be accomplished in part with the addition of Portland cement or various combinations of lime, cement kiln dust, fly ash, or similar reactive materials. The difference between dewatering sediment by amendment with one of these materials and S/S is essentially a function of the amount of reagent that is mixed with sediment. For dewatering, enough reagent is used to eliminate free water; additional reagent may be required for S/S to achieve desired strength, permeability, or resistance to leaching.

Washing is an extraction technology that has been used to remove COCs from sediment. Sediment is mixed in a reaction vessel with water and reagents selected based on the chemicals to be removed. The treatment produces clean sediment that may be reused and a wastewater stream that may be treated more efficiently than treating sediment.

Thermal treatment technologies remove chemicals from soil and sediment by heat application at standard or negative pressure to volatilize chemicals. Volatized contaminants are then chemically altered under high temperatures by oxidation (combustion) or pyrolysis (thermal decomposition without oxidation). Thermal treatment includes incineration and thermal desorption.

Ex-situ treatment operations all require a sizable on- or off-Site treatment area for material handling, staging, treatment, and transport of excavated contaminated material. There are no existing facilities at the Site or room available on-Site for staging, treating, or loading dredged sediment. Based on the absence of on-Site areas capable of staging, treating, or loading dredged sediment; therefore, off-Site property would need to be obtained (leased or purchased) for these activities to be performed. After land acquisition, facilities would need to be designed and built to stage, dewater, and load sediment for transportation if the treatment and disposal facilities are located at a remote location. Based on space limitations, the treatment facility is assumed to be located off-Site at an adjacent or remote location. The establishment of off-Site facilities for sediment washing and thermal desorption (including areas for loading, unloading, stockpiling, and treatment) would require significant coordination between agencies and stakeholders to acquire the necessary lands and permits. However, the incineration technology is currently available from two permitted off-Site facilities in the vicinity of the Site and would not require the acquisition of land or facility operation permits.

Additionally, as discussed in Appendix A, there are only a limited number of vendors identified for the sediment washing and thermal desorption treatment technologies; therefore, the availability of the equipment and expertise necessary for the implementation of these technologies throughout the duration of treatment should be considered prior to selection.

4.4.1.2 Effectiveness

Ex-situ treatment technologies address the chemically impacted sediment by removing the sediment from the aquatic environment and transferring it to upland operations for handling and treatment of the chemically impacted material. S/S, sediment washing, incineration, and thermal desorption are viable ex-situ treatment options that have been shown to effectively and safely treat soil, sediment, and debris impacted by organic compounds, including PCBs. In general, these technologies are applicable for any of the SMAs at a site where dredging operations can occur.

All ex-situ treatment technologies require removal of the chemically impacted material from the Site prior to treatment. The RAOs discussed in Section 3 would be achieved by the removal of the sediment from the aquatic environment. The effectiveness of ex-situ treatment is a reflection of the ability of the technology to immobilize, transform, or destroy COCs prior to disposal or reuse of the treated sediment.

4.4.1.3 Cost

The basis for the development of estimated unit costs for treatment with adsorbent amendments is described in Appendix A. All remedial alternatives that involve off-Site treatment or disposal will require first dredging the sediment and also dewatering the sediment to transport it off-Site. The costs of dredging and dewatering are provided in Section 4.3.5. The dewatering cost includes treatment with an amendment (Portland cement) to improve the handling characteristics of the sediment. The incremental cost for S/S would only be the cost of any additional S/S reagent and mixing time that may be required to meet particular strength or other criteria. No separate cost has been developed for S/S. The estimated range of costs for sediment washing is \$57 to \$76 per cy, the estimated cost for incineration is \$1,100 to \$1,400 per cy, and the estimated cost for thermal desorption is \$130 to \$460 per cy. These costs assume a unit weight of 1.3 tons per cy and include the cost of transporting sediment to the treatment facility. The cost for incineration assumes the sediment would be treated at an existing commercial facility. For other methods of treatment, for which there are no existing facilities, locations would need to be identified, acquired, and permitted to accommodate temporary treatment.

4.4.1.4 Summary

Incineration is capable of removing contaminants from contaminated media and chemically altering the COCs to harmless constituents. Incinerators operating in compliance with environmental permits have been shown to effectively and safely treat soil, sediment, and debris contaminated with PCBs, PAHs, and BEHP. S/S would immobilize the COCs and bind the excess moisture in the sediment in preparation for secure disposal. While sediment washing and thermal desorption technologies can effectively remove and destroy, respectively, COCs from chemically impacted sediments, both have low implementability rankings due to a lack of technology availability from multiple vendors and higher costs; therefore, both process options have been screened out from further consideration in the FS. The screening evaluation of ex-situ treatment technologies is summarized in Table 4-9.

Table 4-9
Ex-situ Treatment Screening Summary

GRA	Technology Type	Process Option	Implementability	Effectiveness	Cost	Screening Decision
Ex-situ Treatment	Immobilization	S/S	Moderate	High	Low to Moderate	Retained[1]
	Separation and Extraction	Washing	Low	Moderate to High	Moderate	Not Retained
	Thermal	Incineration	Moderate	High	High	Retained[1]
		Thermal Desorption	Low	Moderate to High	High	Not Retained

Notes:
[1] Immobilization (by S/S) and thermal treatment (by incineration) have been retained as potential ex-situ treatment technologies for sediment if removal is required.

4.4.2 Preliminary Disposal Technologies

A variety of the potential disposal options for dredged sediment are assessed in this section. Disposal options can be divided into aquatic disposal where: 1) the dredged sediment is confined in a disposal unit that is below the typical surface-water elevation and upland disposal, and 2) where the dredged sediment is confined at an elevation that is above normal surface water. Aquatic disposal can be further subdivided into confined aquatic disposal (CAD) facilities, nearshore confined disposal facilities (nearshore CDF), and open-water disposal. These options are described in Section 4.4.2. Upland disposal options can be divided into upland CDFs and landfills; these options are described in Section 4.4.3. Beneficial use of the dredged sediments is discussed in Section 4.4.4.

4.4.2.1 Aquatic Disposal

4.4.2.1.1 Confined Aquatic Disposal

In a CAD, dredged sediments are placed in an aquatic location in a naturally occurring depression, in an excavated cell, or in an area segregated from surrounding surface waters with a submerged berm or other containment structure. The CAD is capped with clean material and an erosion-resistant layer, if needed, after the chemically impacted sediment is placed.

For Patrick Bayou, a disposal site would need to be identified and appropriate regulatory approvals obtained prior to beginning implementation of a CAD based remedial action. Engineering controls would be constructed, as necessary, to contain sediment and protect water quality. Following disposal, the CAD would be capped to isolate the confined sediment from potential receptors, and post-closure monitoring would be performed to verify the effectiveness of the containment. While no potential sites for a CAD have been identified at the present time, the use of CAD will be retained for consideration as part of the FS in the event a suitable location is identified.

4.4.2.1.2 Nearshore Confined Disposal Facility

For nearshore CDFs, a disposal cell is created by building a berm or other barrier from the shoreline to isolate the cell from adjacent surface water. The cell is then filled with chemically impacted material up to the water line. Following the placement of chemically impacted sediment, a cap of clean material is placed to a final elevation that is above the water line. CDFs are similar to CADs, except that the vertical berm or barrier is the primary system that controls transport of sediment chemicals back into the surrounding water, given that the cap surface is above the waterline.

As with a potential CAD, a site would need to be identified and approvals obtained for a nearshore CDF prior to implementing the remedial action.

4.4.2.1.3 Open-Water Disposal

Open-water disposal involves transporting dredged sediment to an area where the water depth is greater than required for ongoing uses and releasing the sediment into the water column, where it is deposited at the mudline in an unconfined area. This method of disposal is often appropriate for clean sediment, such as the spoils from maintenance dredging of a navigation channel or berthing area, but is generally not considered for sites with chemically impacted sediment because the material is not confined after placement.

4.4.2.1.4 Implementability

Siting a CAD facility will require identifying an area of water deep enough to provide sufficient capacity for placing a significant portion of the sediment that may be dredged from the Site, allowing for the placement of a multilayer cap that will isolate contaminated sediment, attenuate mobile constituents of concern, and provide protection from erosion. The CAD facility ideally would be located outside of an active navigation channel or any area that is subject to dredging. The CAD facility also should be located near the Site to minimize the cost of transporting the sediment for disposal. A search for such a location near the Site has not been performed but no suitable location on-Site has been identified.

Suitable locations for a nearshore CDF may be easier to find at or near the Site. Such a disposal unit might be created by building a multi-segment berm or other containment structure out from the existing shoreline to isolate an area that would be used to confine dredged sediment. Construction and use of a disposal facility off-Site would require obtaining a permit from the USACE, demonstrating that the disposal facility would not impede navigation, and demonstrating that the disposal facility would not affect potential flooding in the waterway.

Open-water disposal would be subject to permitting by the USACE. As described in Section 4.4.2.1.3, open-water disposal is generally not appropriate for management of chemically impacted sediment, and thus has been screened out from further consideration in the FS.

4.4.2.1.5 Effectiveness

CAD facilities and nearshore CDFs have been successfully used to contain chemically impacted sediment. Mathematical evaluations of chemical fate and transport, as well as the erosive potential of surface water on the containment structure would be used to evaluate the potential impacts from the disposal unit on the surrounding environment. At sites with similar Site-specific COCs, long-term modeling has been used to demonstrate that a properly constructed and maintained disposal facility can contain such chemicals indefinitely.

4.4.2.1.6 Cost

If the FS evaluates remedial alternatives that incorporate aquatic disposal, Site-specific conceptual designs and cost estimates will be prepared to assist in the evaluation of this disposal option. At similar sites, cost estimates for aquatic disposal (including the design, permitting, construction, filling, closure, and post-closure maintenance and monitoring of the units) have been in the range of $60 to $120 per ton for disposing of sediment in a CAD or nearshore CDF.

4.4.2.1.7 Summary

Disposal in a CAD or nearshore CDF (aquatic disposal) is a potentially effective method to permanently contain chemically impacted sediment. A preliminary review of potential sites for aquatic disposal suggests that a nearshore CDF may be built on-Site or near the Site. No potential sites for a CAD facility have been identified yet. In contrast, open-water disposal is unlikely to be a suitable method for disposing of chemically impacted sediment from the Site. Disposal in a CAD facility or a nearshore CDF is retained for further consideration, but open-water disposal is not retained. The screening summary for aquatic disposal is provided in Table 4-10.

Table 4-10
Aquatic Disposal Screening Summary

GRA	Technology Type	Process Option	Implementability	Effectiveness	Cost	Screening Decision
Aquatic Disposal	Confined Aquatic Disposal	N/A	Low	High	Moderate	Retained[1]
	Nearshore Confined Disposal	N/A	Moderate	High	Moderate	Retained[1]

GRA	Technology Type	Process Option	Implementability	Effectiveness	Cost	Screening Decision
	Open-Water Disposal	N/A	Low	Low	Moderate	Not Retained

Notes:
[1] Confined aquatic disposal and nearshore confined disposal have been retained as potential disposal technologies for sediment if removal is required.

4.4.3 Upland Disposal

There are two types of upland disposal considered: commercial permitted landfills and a site-specific upland CDF. Upland disposal at a commercial landfill would involve dewatering the sediment and trucking it to a landfill for secure disposal in a lined engineered cell that would be capped upon completion. Landfills are designed to prevent the release of COCs into soil, groundwater, and surface water. Groundwater near landfills is monitored to confirm that groundwater quality is protected. Treated sediment may be appropriate for use as daily cover, which may reduce the cost for landfill disposal. An upland CDF would need to be designed, permitted, and built to manage sediment removed from Patrick Bayou. The FS will consider whether this is a viable option, including consideration of the volume of material that may be removed from the Site under various remedial alternatives. Landfill operators are required to obtain permits issued by State agencies; materials from CERCLA sites can be taken only to landfills operated in compliance with their permits (Off-Site Rule, 40 CFR 300.440).

4.4.3.1 Landfill Disposal

Sediment dredged from the Site would be taken by barge or pumped to a processing and transloading facility where the sediment would be dewatered and loaded onto trucks. Depending on the distance to the landfill and the volume of sediment to be removed, rail transport may be more cost-effective than truck transport. Loading sediment onto rail cars would require more space at a transfer facility and may require the extension of a rail spur to a dock, if available. Therefore, this option would likely be cost-effective only if a large volume of sediment is to be disposed of at a landfill remote from the Site.

The sediment could be dewatered on barges and loaded directly onto trucks, if space is not available at an upland facility to stage and dewater the sediment. Dewatering would consist of collecting the water that readily separates from the sediment and then amending the sediment to absorb sufficient residual moisture to allow transportation and disposal of the sediment without releasing potentially chemically impacted water. A variety of amendments have been used for dewatering sediment, including Portland cement, fly ash, diatomaceous earth, and a variety of cellulose-based materials. The water that would be drained from the sediment in the first stage of dewatering could be treated, if necessary, and released to surface water in compliance with a permit or collected and transported to a permitted wastewater treatment facility. One of the disadvantages of dewatering using amendments is that it increases the weight (and therefore cost) or material to be disposed. Dewatering using Portland cement or other pozzolanic materials would be the same as S/S discussed in Section 4.4.1, if sufficient reagent is used to immobilize chemicals and improve the strength of the material.

In the FS, permitted landfill facilities will be evaluated for use as potential disposal sites. The sites will have to be properly permitted and approved by the USEPA prior to use. One consideration included within this evaluation will be the potential for long-term liability resulting from off-Site disposal.

4.4.3.2 Upland CDF Disposal

Dredged sediment could be transported by barge or pipeline to a disposal cell constructed at or near the Site. Unlike disposal in a commercial landfill, disposal in the upland CDF would not require the transportation of sediment from the Site on public roadways. If the CDF would be located off-Site, the evaluation would include the potential for long-term liability.

4.4.3.3 Implementability

Upland disposal in a landfill or a CDF is a common method for disposal of dredged sediment. Several landfills are located within a short distance of the Site. The detailed evaluation in the FS will consider whether the chemically impacted sediment meets the waste acceptance criteria established for these facilities. Upland disposal will also require identifying and permitting a transfer station for offloading sediment from barges, dewatering sediment, and loading sediment onto trucks for transportation to the landfill. The transload facility will need to have a dock with sufficient water depth to accommodate barges of sediment and sufficient upland area for staging dewatering amendment, dewatering sediment, loading trucks, managing truck traffic, containing decant water, and, potentially, treating the water for discharge. Transloading would likely not be necessary for disposal at an upland CDF located near the Site.

4.4.3.4 Effectiveness

Landfills provide secure, permanent containment of waste. The effectiveness of liners and leachate collection systems has been well documented and the COCs in the sediment from the Site have low mobility that will be further reduced by dewatering the sediment. The effectiveness of landfill containment systems is monitored as stipulated in landfill operating permits.

The transportation of sediment from the dredge site to the landfill has potential for short-term impacts associated with release of COCs due to accidental spills of material, additional truck traffic on roads from the transload facility to the landfill, and emissions from trucks and other equipment used to load and transport sediment. BMPs can be used at all stages of transportation to reduce the potential for accidental releases of chemically impacted material. Some examples of potential BMPs are:

- Filtering transport barge effluent to contain suspended solids prior to discharge.
- The use of a spill apron between the dock and barge to catch material dropped from transfer buckets and direct spills back to the barge or into the contained upland facility.
- The use of pavement and curbing in the truck loading area, entrance, and exit to provide secondary containment for material in the transload facility.
- The use of an enclosed box to provide primary containment of chemically impacted material in the transload facility and a location for mixing sediment with dewatering amendment.
- Inspection of trucks for spilled material on the exterior of the truck body or on tires, and the use of a wheel wash, if necessary, before the truck leaves the transload facility.
- Regular sweeping and washing of the truck loading area and approaches to remove spilled material and minimize the potential for such material being picked up and spread by tires.

CDFs provide effective containment of sediment and COCs. Since disposal in an upland CDF would not require transloading sediment from barges onto trucks or transporting sediment on public highways, many of the considerations discussed in the preceding paragraph would not apply to remedial alternatives that would incorporate CDF disposal.

4.4.3.5 Cost

A preliminary cost estimate for upland disposal was prepared considering the costs to develop the transfer facility, offload sediment from barges, dewater the sediment, and transload the dewatered material to trucks for transportation and disposal. The cost estimate includes costs to monitor water quality during the operation of the transfer facility. The estimated unit cost for transportation and upland disposal at a commercial landfill is $80 to $100 per ton. Costs were not developed for upland CDF disposal because no specific on-Site or nearby locations for this disposal option have been identified as part of the screening process.

4.4.3.6 Summary

Upland disposal in a commercial landfill or an upland CDF is a well-established and viable method for secure, long-term containment of dredged sediment. Upland disposal at a commercial landfill would occur in an existing permitted facility; therefore, a new disposal site would not need to be developed before remedial action could begin, and the disposal site owner would be responsible for long-term maintenance and monitoring of the facility if this disposal option were selected.

For landfill disposal, a transfer facility would need to be developed to transload sediment from barges to trucks. The transfer facility would be decontaminated and closed at the end of the remedial action, so there would be no need for long-term maintenance or monitoring. Upland disposal at a commercial landfill would require trucking dredged sediment from the Site to the disposal facility, which would increase short-term risks associated with increased truck traffic, exhaust emissions, and potential release of materials impacted by Site-specific COCs on public roads.

Although a specific on-Site or nearby location has not been identified for developing such a facility, upland disposal at a CDF is another option for managing dredged material. An on-Site CDF would need to be properly designed to ensure containment of dredge material and protection of the environment, and would potentially be subject to long-term maintenance and monitoring by the owner. Because an upland CDF would theoretically be sited as close to the dredging operation as possible, there are fewer considerations related to developing an offload and transfer facility compared to the commercial landfill disposal alternative.

Both disposal options are retained for further consideration. The screening summary for upland disposal is provided in Table 4-11.

Table 4-11
Upland Disposal Screening Summary

GRA	Technology Type	Process Option	Implementability	Effectiveness	Cost	Screening Decision
Upland Disposal	Landfill	N/A	Moderate	High	Moderate	Retained[1]
	Upland CDF	N/A	Low	Moderate to High	Moderate to High	Retained[1]

Notes:
[1] Commercial landfilling and upland confined disposal have been retained as potential disposal technologies for sediment if removal is required.

4.4.4 Beneficial Use

Dredged sediment is sometimes used as fill in the aquatic environment, such as for beach or wetland nourishment, or in upland areas where fill is needed to achieve desired topographic contours. Sediment for beneficial use must meet certain criteria for soil type (e.g., grain size) and chemical concentrations depending on where and how the fill is proposed to be used. The sediment that may be dredged from the Site is not expected to meet criteria for beneficial use. Therefore, this disposal technique has been screened from further consideration in the FS.

4.4.5 Summary of Retained Remedial and Disposal Technologies

Remedial alternatives that include sediment removal will require one or more disposal technologies for permanent placement of the sediment. In-water and upland disposal options are both potentially feasible and will be evaluated in the FS. In-water disposal options offer advantages associated with close proximity to the sediment-removal location: 1) fewer handling steps (no transload to upland transportation); 2) reduced fuel use and emissions associated with transportation; and 3) less potential for releases of contaminated material in transportation. The upland disposal options offer the advantages of essentially unlimited capacity, not having to build a disposal facility where commercial landfills are used, and long-term monitoring being performed by the commercial landfill that would accept the sediment. Additional considerations that may need to be evaluated in the selection or design of disposal options are the potential for in-water disposal units to affect the flow within the Site, potential erosive forces that in-water disposal units would need to resist, and the ability of in-water disposal units to contain COCs.

4.5 Summary of Remedial and Disposal Technology Screening

Table 4-12 provides an overall summary of the remedial technology screening results discussed in this section. The retained technologies and options will be used to assemble alternatives for further evaluation, and ultimately for more detailed consideration during the FS and remedial design. Table 4-13 provides a summary of the screening of ex-situ treatment and disposal options that are potentially applicable if sediment removal is incorporated into a remedial alternative.

Table 4-12
Remedial Technology Screening Summary

GRA	Technology Type	Process Option	Implementability	Effectiveness	Cost	Screening Decision
Institutional Controls	Administrative and Legal Controls	Access and property use restrictions	High	High	Low	Retained for all areas
		Informational devices (e.g., signage and fish consumption advisories)	High	High	Low	Retained for all areas
Natural Recovery	Monitored Natural Recovery	Sedimentation	High	High	Low	Retained for specific areas[1]

GRA	Technology Type	Process Option	Implementability	Effectiveness	Cost	Screening Decision
		Placement of thin layer of clean cover	High	High	Low to Moderate	Retained for specific areas[1]
In-situ Containment	Capping	ACBM	High	High	High	Retained for all areas
		Aggregate and Natural Materials	Limited[2]	High	Moderate to High	Retained for all areas
In-situ Treatment	Physical-Immobilization	Adsorptive Amendments	Moderate to High	High	Moderate to High	Retained for specific areas[3]
Removal[4]	Dry Excavation	Soil Excavators	Low	Moderate	High	Retained for specific areas[5]
	Dredging	Mechanical Dredging	Moderate	Moderate	High	Retained for specific areas[6]
		Hydraulic Dredging	Moderate	Moderate	High	Retained for all areas[4]

Notes:
[1] Retained for stable areas of the Site with a high NSR.
[2] Conventional aggregate caps tend to be thicker than ACBM and have a greater impact on flood storage within the Site. Their application as a remedial technology within the Site is expected to be more limited, and will be evaluated in greater detail in the FS.
[3] Retained for shallow sediment (within approximately 10 cm of the sediment-water interface) in stable areas of the Site with a high NSR.
[4] Sediment removal is potentially applicable in conjunction with other remedial technologies, such as in-situ containment, to maintain hydraulic capacity in constrained portions of the channel.
[5] Dry excavation is potentially applicable in limited nearshore areas.
[6] Mechanical dredging is potentially applicable in areas with sufficient water depth to support equipment.

Table 4-13
Ex-Situ Treatment and Disposal Technology Screening Summary[1]

GRA	Technology Type	Process Option	Implementability	Effectiveness	Cost	Screening Decision
Ex-situ Treatment	Immobilization	S/S	Moderate	High	Low to Moderate	Retained
	Separation and Extraction	Washing	Low	Moderate to High	Moderate	Not Retained
	Thermal	Incineration	Moderate	High	High	Retained

GRA	Technology Type	Process Option	Implementability	Effectiveness	Cost	Screening Decision
		Thermal Desorption	Low	Moderate to High	High	Not Retained
Aquatic Disposal	Confined Aquatic Disposal	N/A	Low	High	Moderate	Retained
	Nearshore Confined Disposal	N/A	Moderate	High	Moderate	Retained
	Open-Water Disposal	N/A	Low	Low	Moderate	Not Retained
Upland Disposal	Landfill	N/A	Moderate	High	Moderate	Retained
	Upland CDF	N/A	Low	Moderate to High	Moderate to High	Retained

Notes:
[1] Ex-Situ Treatment and disposal technologies are considered for management of sediment that may be removed from the Site.

5 TECHNOLOGY SUMMARY

5.1 Technology Summary

Section 4 screened different technologies with Tables 4-12 and 4-13 presenting a summary of the results of the technology screening. This section further describes and summarizes the various considerations for each type of SMA for development of the remedial alternatives that will be performed in the FS. Below, natural recovery, in-situ treatment, containment, and removal limitations are further discussed. The section concludes by summarizing technologies by SMA that are proposed to be carried forward into the FS.

5.1.1 Natural Recovery Constraints

Natural recovery is an ongoing process occurring in certain areas of the Site, as described in Section 4.3.2. As such, MNR is a technology that is applicable for all areas of the Site that are considered net depositional, but its effectiveness may be limited for -NE_{100} SMAs. EMNR entails the placement of a thin layer of clean material to accelerate the natural recovery process. Placement of EMNR material is not expected to be compatible with high flow areas, because loss of the material would occur and limit the effectiveness of the clean material; however, this may be mitigated with the completion of the planned upstream stormwater detention basin in the City of Deer Park. Thus, EMNR would require further study in higher-energy portions of the Site, such as the -NE_{100} SMA areas identified in the hydraulic model, if it were to be proposed as part of an integrated remedy for the Site.

5.1.2 In-situ Treatment

In-situ treatment may be applicable in certain areas of the Site, particularly those SMAs that do not have the -NE_{100} designation, where Site sediments are expected to be more stable and the amendment will not be eroded. When used in conjunction with containment and beneath an armored cap, in-situ treatment in -NE_{100} SMAs is an implementable alternative that can be effective.

5.1.3 Containment Constraints

Due to the potential to constrain flow and cause flooding, containment may not be a practicable standalone technology for all areas of the Site. Selective sediment removal may be necessary in certain SMAs to provide for adequate flood storage within the Site and to compensate for the loss of storage due to the containment cap thickness. As previously mentioned, the use of containment caps over broad areas of the Site would need to consider any potential changes in flood elevations. Containment would need to be sufficiently stable under hydrodynamic forces, and evaluating armoring needs would be necessary as part of the FS, particularly in those SMAs with an -NE_{100} modifier in their designation.

5.1.4 Removal Constraints

Due to implementability issues, removal may not be a practicable alternative for all areas of the Site. Areas beneath fixed ST SMAs are typically very difficult to access and might require complete demolition and replacement of the structure to facilitate removal. Alternatively, removal might compromise the structural integrity of structures as sediment is removed and passive resistance for foundation elements is reduced. Thus, for SMAs delineated as ST, removal might not be considered practicable and in-situ containment would be selected instead.

For the gunite-lined portion of the channel (sidewalls only), i.e., AB SMA, a more detailed evaluation of the potential impacts and implementability of removal would need to be performed in the FS for this technology to be considered effective. Access to this portion of the Site is severely constrained by the operating facilities on both banks. Removal in areas with significant debris or hard bottom conditions (such as the AB SMA) will likely result in higher sediment resuspension, release, and water quality impacts. Finally, removal of the concrete-lined banks could destabilize the slopes and potentially compromise structures located on the banks of this portion of the Site.

The vertical profile of impacted sediments indicates that concentrations tend to increase with depth. To the extent that removal is considered in any SMA, the depth profile of concentration must be understood, because there will be specific areas where the increasing concentration poses unacceptable risk from removal due to generated residual and water quality impacts. Where high concentrations directly overlay the relatively stiff Beaumont Formation Clay layer and/or rock/debris areas, this transition in density would complicate removal and potentially increase residuals generation, as has been shown on other sites with relatively hard bottom conditions (USACE 2008).

5.1.5 Summary of Retained Technologies by SMA

Table 5-1 summarizes technologies suitable for each SMA based on the discussion provided in Sections 4 and 5.1.

5.2 Screening Conclusions

As discussed in Section 2.3.3, data presented in previous reports indicate groundwater from each facility has insignificant measurable interaction with and contributes no toxicity to Patrick Bayou sediments/surface water. Based on these evaluations and outcomes, groundwater interaction between sediments and surface water are not considered a pathway of concern in regard to remedial planning for sediments at the Site. Thus, the remedial action objectives focus on directly addressing sediment impacts to reduce overall risk associated with the Site.

Based on the screening presented in this document, the following remedial technologies are not considered applicable to Site sediments and thus will not be carried forward into the FS:

- Treatment by thermal desorption
- Treatment by sediment washing
- Disposal in an unconfined open water site
- Beneficial reuse of sediments

For natural recovery technologies, the effectiveness of the technology may be limited by hydrodynamic conditions, and further study would be necessary to demonstrate that potential erosion in these areas would not extend the remedy time frame beyond acceptable limits. If removal is to be considered in the AB SMA, additional study of the potential impacts of dredging (sediment resuspension, release, and water quality impacts), as well as the potential to destabilize the slope and damage the operating facilities on the banks in this area would need to be studied in more detail in the FS.

For the remaining technologies, development and screening of remedial alternatives will be performed in accordance with CERCLA guidance, and SMA-specific constraints will be considered as part of the effectiveness and implementability evaluation. As has been shown for many CERCLA sediment sites, an integrated approach that combines a variety of technologies is expected to provide the optimal combination of implementability, effectiveness, and cost for the Site.

6 REFERENCES

Anchor (Anchor Environmental, LLC), 2006. *Preliminary Site Characterization Report*. Patrick Bayou Superfund Site Deer Park, Texas. Prepared for U.S. Environmental Protection Agency and Patrick Bayou Joint Defense Group. May 2006.

Anchor 2007a. *Work Package 2 Work Plan, Hydrodynamic Field Data Collection and Contaminant Source Evaluation.* Patrick Bayou Superfund Site Remedial Investigation, Deer Park, Texas. Prepared for U.S. Environmental Protection Agency and the Patrick Bayou Joint Defense Group. January 2007.

Anchor 2007b. *Work Package 2 Vertical Profiling Hydrodynamic Field Data Collection and Contaminant Source Evaluation*. Patrick Bayou Superfund Site, Deer Park, Texas. Prepared for U.S. Environmental Protection Agency and the Patrick Bayou Joint Defense Group. April 2007.

Anchor QEA, 2010. *Sediment and Surface Water Contaminant of Potential Concern Delineation Report.* Patrick Bayou Superfund Site. Deer Park, Texas. Prepared for USEPA and Patrick Bayou Joint Defense Group. May 2010.

Anchor QEA, 2011. *Sediment Transport Modeling Report*. Prepared for Prepared for U.S. Environmental Protection Agency and Patrick Bayou Joint Defense Group. September 2011.

Anchor QEA, 2012a. *Upstream Patrick Bayou Characterization Report*. Patrick Bayou Superfund Site. Deer Park, Texas. Prepared for Patrick Bayou Joint Defense Group. February 2012.

Anchor QEA, 2012b. *Baseline Human Health Risk Assessment Patrick Bayou Superfund Site*. Prepared for U.S. Environmental Protection Agency and Patrick Bayou Joint Defense Group. December 2012.

Anchor QEA, 2013. *Baseline Ecological Risk Assessment Patrick Bayou Superfund Site*. Prepared for U.S. Environmental Protection Agency and Patrick Bayou Joint Defense Group. March 2013.

Bridges, T., K. Gustavson, P. Schroeder, S. Ells, D. Hayes, S. Nadeau, M. Palermo, and C. Patmont, 2010. Dredging Processes and Remedy Effectiveness: Relationship to the Four Rs of Environmental Dredging. *Integrated Environmental Assessment and Management*, 2010, 6:619–630.

Connolly J.P., J.D. Quadrini, and J.J. McShea, 2007. Overview of the 2005 Grasse River Remedial Options Pilot Study. In: *Proceedings, Remediation of Contaminated Sediments—2007*. Savannah, Georgia. Columbus (OH): Battelle.

Denton, W., 2006. Personal communication. Texas Parks and Wildlife Department. February 17, 2006.

Lubrizol Corporation (Lubrizol), 2011. *Evaluation of the Geologic and Groundwater Conditions at the Lubrizol Corporation, Deer Park, Texas*. April 13, 2011.

National Research Council (NRC), 2007. *Sediment Dredging at Superfund Megasites – Assessing the Effectiveness*. National Research Council, Washington, DC: National Academy Press.

Palermo, M.R., J.E. Clausner, M.P. Rollings, G.L. Williams, T.E. Myers, T.J. Fredette, and R.E. Randall, 1998. *Guidance for Subaqueous Dredged Material Capping*. Technical Report DOER-1. U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi. Website: http://www.wes.army.mil/el/dots/doer/pdf/doer-1.pdf.

Patmont, C., and M. Palermo, 2007. Case Studies of Environmental Dredging Residuals and Management Implications. Paper D-066, in: Remediation of Contaminated Sediments—2007, Proceedings of the Fourth International Conference on Remediation of Contaminated Sediments. Savannah, Georgia. January 2007.

Reible, D., X. Lu, J. Galjour, and Y. Qi, 2008. The use of organoclay in managing dissolved contaminants relevant to contaminated sediments. CETCO Technical Reference 840. TR 840. June 2008.

Shell Oil Company (Shell), 2009. *Groundwater Evaluation, Shell Deer Park Facility and Patrick Bayou Superfund Site, Deer Park, Texas*. July 2009.

Texas Department of Health (TDH), 2003. Public Health Assessment Patrick Bayou Deer Park, Harris County, Texas. February 2003.

USACE, 2008. *Technical Guidelines for Environmental Dredging of Contaminated Sediments*. ERDC/EL TR-08-29. United States Army Corps of Engineers. September 2008.

U.S. Environmental Protection Agency (USEPA) and U.S. Army Corps of Engineers (USACE), 2000. *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study*. EPA 540-R-00-002. July 2000.

USEPA, 1988. *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA*. EPA/540/G-89/004.

USEPA, 1995. *Land Use in the CERCLA Remedy Selection Process*. OSWER Directive No. 9355.7-04

USEPA, 1997. *Rules of Thumb for Superfund Remedy Selection*. U.S. Environmental Protection Agency. Office of Emergency and Remedial Response, Washington, DC. EPA 540-R-97-013.

USEPA, 1998. *Assessment and Remediation of Contaminated Sediments (ARCS) Program. Guidance for In-situ Subaqueous Capping of Contaminated Sediments*. EPA 905-B96-004. September 1998.

USEPA, 2000. *The Feasibility Study: Detailed Analysis of Remedial Action Alternatives*. USEPA, Office of Emergency and Remedial Response. Hazardous Site Control Division OS-220. http://www.epa.gov/superfund/policy/remedy/pdfs/93-55301fs4-s.pdf

USEPA, 2005. *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites*. OSWER 9355.0-85. EPA-540-R-05-012. December 2005.

USEPA, 2009. "EPA Region 6 Clean and Green Policy." September 1, 2009.

Weston Solutions (Weston), 2007. *Patrick Bayou Groundwater Evaluation, OxyVinyls, Deer Park Facility*. Memorandum dated October 17, 2007.

TABLES

Table 2-1
Geotechnical Testing Results

Location ID	Recovery Length[1] (ft)	Material	USCS	General Description	Water Content[2] (ASTM D 2216)	Specific Gravity (ASTM D 854)	Atterberg Limits (ASTM D 4318)			Grain Size (ASTM D 422)				
							Liquid Limit	Plastic Limit	Plasticity Index	Percent Gravel	Percent Sand	Percent Fines	Clay-sized Particle Content (0.005 mm)	Clay-sized Particle Content (0.002 mm)
PB-009	4.4	Sediment	CH	Black Sandy Clay	76%	2.57	51	20	31	0	47%	53%	23%	20%
PB-022	5.9	Sediment	CH	Black Clay with Fine Sand	110%	2.51	74	29	45	0	27%	73%	37%	33%
PB-030	0.4	Beaumont Clay	CH	Dark Grey Silty Clay	31%	2.68	42	21	21	0	27%	73%	40%	37%
PB-036	7.4	Sediment	CH	Black Clay with Silt	104%	2.57	74	29	45	0	12%	88%	40%	35%
PB-047	6.1	Sediment	CH	Black Silty Clay with Sand	120%	2.47	80	31	49	0	28%	72%	30%	24%
PB-063	2.8	Sediment	CH	Black Clay with Silt and Shell	92%	2.57	73	27	46	0	30%	70%	44%	38%

Notes:
1. Percent recovery for each of the cores ranged from 99 to 100 percent. Since the percent recovery for all cores is essentially 100 percent, the recovery length also represents the depth of the bottom of the core.
2. Natural moisture content is defined in geotechnical engineering as the mass of water divided by the mass of solids rather than the mass of water divided by the total mass of sample. The equivalent range of water content, presented as a more typical percentage, for the values presented in this table are 43 to 55 percent (mass of water divided by total mass of sample).

Table 2-2
Descriptions of Outfalls Related to the Patrick Bayou Site

Outfall	Description
Lubrizol Outfalls	
001	Treated process wastewater discharging into the culvert running between Deer Park and upper reach (start of gunite)
002	Stormwater discharge discharging at the mouth of the culvert exit in the upper reach
003	Stormwater discharge discharging approximately 1/3 of distance from the culvert exit to end of gunite
004	Stormwater discharge discharging approximately 4/5 of distance from the culvert exit to end of gunite
005	Stormwater discharge discharging approximately 4/5 of distance from the culvert exit to end of gunite
006	Stormwater discharge discharging into the culvert running between Deer Park and upper reach (start of gunite)
007	Stormwater discharge discharging into the East Fork of Patrick Bayou at northeast corner of Lubrizol property
Shell Outfalls	
C101/001	001 -Maintenance outfall, 101 -Excess stormwater outfall discharging into Patrick Bayou
C002	Stormwater and domestic wastewater discharging into Patrick Bayou
C003	Stormwater and domestic wastewater discharging into Patrick Bayou
R-001	Utility wastewater and stormwater discharging into Patrick Bayou
R-002	Stormwater and non-process wastewater discharging into Patrick Bayou
R-003	Stormwater and non-process wastewater discharging into Patrick Bayou
R-004	Stormwater and fire water discharging into Patrick Bayou
R-009	Stormwater and fire water discharging into Patrick Bayou
OxyChem Outfalls	
002	Non-contact flow-through water from Houston Ship Channel outfall, outfall discharging into Patrick Bayou approximately 4,300 feet from mouth of the bayou
003	Non-contact flow-through water from Houston Ship Channel outfall, outfall discharging into Patrick Bayou approximately 3,600 feet from mouth of the bayou
Other Outfalls	
Deer Park WWTP -001	City of Deer Park wastewater treatment discharge; discharging to drainage ditch that flows to Patrick Bayou south of State Highway 225
Praxair, Inc. -001	Utility wastewater that discharges to unnamed ditch that flows to East Fork of Patrick Bayou
Rohm-Haas -003	Non-process area stormwater that discharges to the East Fork of Patrick Bayou

Notes:
1. WWTP = Wastewater Treatment Plant

Table 3-2
Potential ARAR Screening for the Patrick Bayou Superfund Site, Remedial Alternatives Technology Screening

Potential ARARs[1]	Citation	Summary	Comment
Federal			
Clean Water Act (CWA): Criteria and standards for imposing technology-based treatment requirements under §§ 309(b) and 402 of the Act	33 U.S.C. §§ 1319 and 1342 (implementing regulations at 40 CFR Part 125 Subpart A)	Both on-site and off-site discharges from CERCLA sites to surface waters are required to meet the substantive CWA (National Pollutant Discharge Elimination System) NPDES requirements (USEPA 1988).	On-site discharges must comply with the substantive technical requirements of the CWA but do not require a permit (USEPA 1988). Off-site discharges would be regulated under the conditions of a NPDES permit (USEPA 1988). Standards of control for direct discharges must meet technology-based requirements. Best conventional pollution control technology (BCT) is applicable to conventional pollutants. Best available technology economically achievable (BAT) applies to toxic and non-conventional pollutants. For CERCLA sites, BCT/BAT requirements are determined on a case-by-case basis using best professional judgment. This is likely to be a potential requirement only if treated water or excess dredge water is discharged during implementation.
CWA Sections 303 and 304: Federal Water Quality Criteria	33 U.S.C. §§1313 and 1314 (Most recent 304(a) list as updated to issuance of ROD)	Under §303 (33 U.S.C. §1313), individual states have established water quality standards to protect existing and attainable uses (USEPA 1988). CWA §301(b)(1)(C) requires that pollutants contained in direct discharges be controlled beyond BCT/BAT equivalents (USEPA 1988). CERCLA §121(d)(2)(B)(i) establishes conditions under which water quality criteria, which were developed by USEPA as guidance for states to establish location-specific water quality standards, are to be considered relevant and appropriate. Two kinds of water quality criteria have been developed under CWA §304 (33 U.S.C. §1314): one for protection of human health, and another for protection of aquatic life. These requirements include establishment of total maximum daily loads (TMDL).	The FS will consider the ability of remedial alternatives to satisfy established water quality criteria. Best management practices (BMPs) would be established for remedial actions and applied during construction. Water quality would also be monitored during construction and additional BMPs may be implemented if necessary to protect water quality. Where water quality state standards contain numerical criteria for toxic pollutants, appropriate numerical discharge limitations may be derived for the discharge and considered (USEPA 1988). Where state standards are narrative, either the whole-effluent or chemical-specific approach may generally be used as a standard of care (USEPA 1988).
CWA Section 307(b): Pretreatment standards	33 U.S.C. §1317(b)	CERCLA §121(e) states that no federal, state, or local permit for direct discharges is required for the portion of any removal or remedial action conducted entirely on-site (the aerial extent of contamination and all suitable areas in close proximity to the contamination necessary for implementation of the response action) (USEPA 1988).	If off-site discharges from a CERCLA response activity were to enter receiving waters directly or indirectly, through treatment at a Publicly Owned Treatment Works (POTWs), they must comply with applicable Federal, State, and Local substantive requirements and formal administrative permitting requirements (USEPA 1988). This requirement may be triggered by disposal methods for waste.
CWA Section 401: Water Quality Certification	33 U.S.C. §1341	Requires applicants for Federal permits for projects that involve a discharge into navigable waters of the U.S. to obtain certification from state or regional regulatory agencies that the proposed discharge will comply with CWA Sections 301, 302, 303, 306, and 307.	Proposed activities that are on-site would not require a Federal permit. Therefore, certification is not legally required for on-site actions. Certification would be required for off-site actions. For on-site or off-site actions, certification should occur as part of the state identification of substantive state ARARs (USEPA 1988). Compliance with water quality criteria is discussed under CWA Sections 303 and 304.

[1] ARARs are applicable or relevant and appropriate requirements of Federal or state environmental laws and state facility siting laws. CERCLA section 121(d) requires that remedial actions generally comply with ARARs. The USEPA has stated a policy of attaining ARARs to the greatest extent practicable on remedial or removal actions (USEPA 1988). USEPA also stated that certain nonpromulgated Federal and state advisories or guidelines would be considered in selecting remedial or removal actions; these guidelines are referred to as TBCs, or "to be considered."

Table 3-2
Potential ARAR Screening for the Patrick Bayou Superfund Site, Remedial Alternatives Technology Screening

Potential ARARs[1]	Citation	Summary	Comment
CWA Section 404 and 404(b)(1): Dredge and Fill	33 U.S.C. §1344 (b)(1) (implementing regulations at 33 CFR 320 and 330; 40 CFR 230)	Discharges of dredged and fill material into waters of the U.S. must comply with the CWA §404 (33 U.S.C. 1344) guidelines and demonstrate the public interest is served (USEPA 1988).	Patrick Bayou is a water of the U.S. (USEPA 2007). Dredge and fill permits are applicable to dredging, in-water disposal, capping, construction of berms or levees, stream channelization, excavation and/or dewatering within waters of the U.S. (USEPA 1988). Permits are not required, however, for on-site CERCLA actions. Under the 404(b)(1) guidelines, efforts should be made to avoid, minimize, and mitigate adverse effects on the waters of the U.S. and, where possible, select a practicable (engineering feasible) alternative with the least adverse effects. The substantive requirements of Section 404 will be considered in the development and evaluation of remedial alternatives to minimize adverse impacts to waters of the U.S.
Safe Drinking Water Act	42 U.S.C. §300f (implementing regulations at 40 CFR Part 141, et seq.)	The Safe Drinking Water Act is applicable to public drinking water sources at the point of consumption ("at the tap"). Maximum contaminant levels (MCLs) have been established for certain constituents to protect human health and to preserve the aesthetic quality of public water supplies.	Safe Drinking Water Act standards are applicable to public drinking water sources. Patrick Bayou does not supply public drinking water and does not recharge an aquifer used to supply drinking water. Therefore, the Safe Drinking Water Act is not applicable. The MCL for 2,3,7,8-tetrachlorodibenzodioxin may be considered for protecting water quality.
Federal Drinking Water Regulations (Primary and Secondary Drinking Water Standards)[2]	40 CFR 141 and Part 143	USEPA has established two sets of drinking water standards: one for protection of human health (primary) and one to protect aesthetic values of drinking water (secondary) (USEPA 1988). MCLs are applicable to public drinking water sources at the point of consumption.	Safe Drinking Water Act standards are applicable to public drinking water sources. Patrick Bayou does not supply public drinking water and does not recharge an aquifer used to supply drinking water. Therefore, the Safe Drinking Water Act is not applicable. The MCL for 2,3,7,8-tetrachlorodibenzodioxin may be considered for protecting water quality.
Resource Conservation And Recovery Act (RCRA): Hazardous Waste Management	42 U.S.C. §§6921 et seq. (implementing regulations at 40 CFR Parts 260 – 268)	RCRA is intended to protect human health and the environment from the hazards posed by waste management (both hazardous and nonhazardous). RCRA also contains provisions to encourage waste reduction. RCRA Subtitle C and its implementing regulations contain the Federal requirements for the management of hazardous wastes.	This requirement would apply to certain activities if the affected sediments contain RCRA listed hazardous waste or exhibit a hazardous waste characteristic. RCRA requirements are applicable only if waste is managed (treated, stored, or disposed of) after effective date of RCRA requirement under consideration or if CERCLA activity constitutes treatment, storage, or disposal as defined by RCRA.
RCRA: General Requirements for Solid Waste Management	42 U.S.C. §§6941 et seq. (implementing regulations at 40 CFR 258)	Requirements for construction for municipal solid waste landfills that receive RCRA Subtitle D wastes, including industrial solid waste. Requirements for run-on/run-off control systems, groundwater monitoring systems, surface water requirements, etc.	This requirement would be relevant if a landfill was constructed for the disposal of non-hazardous solid waste. There are no specific Federal requirements for non-hazardous waste management; state regulations provide specific applicable requirements for siting, design, permitting, and operation of landfills.
Toxic Substances Control Act (TSCA)	15 USC §2601 et. seq. (implementing regulations at 40 CFR 761)	Potentially applicable to PCB-contaminated sediment or surface water. Requires remedial action of certain PCB releases depending on the concentration of the source material and the date of the release (or the as-found concentration for releases where the date is undetermined). Disposal and treatment requirements are also specified for environmental media if removed depending on total PCB concentrations.	Total PCB concentrations in limited areas of the Site may exceed the regulatory threshold (50 mg/kg, calculated as specified in 40 CFR 761) that would require remedial action and may trigger certain requirements for waste management. TSCA regulations may be insignificant relative to other bases for remedial action. No sediment samples contain total PCB concentrations that would trigger TSCA requirements for disposal by incineration.
Clean Air Act (CAA)	42 U.S.C. §§7401 et seq.	Would apply if dredging and/or excavation activities generate air emissions sufficient to require a permit, greater than 10 tons of any pollutant per year under the CAA operational permit (USEPA 2009).	None of the remedial alternatives is expected to trigger an operational permit.

[2] Underground injection is not anticipated as a part of the potential remedial action. Furthermore, the site is not located in a sole-source aquifer (USEPA 2008). It is also assumed that no wellhead protection area is located near the study area.

Table 3-2
Potential ARAR Screening for the Patrick Bayou Superfund Site, Remedial Alternatives Technology Screening

Potential ARARs[1]	Citation	Summary	Comment
Rivers And Harbors Act of 1899: Obstruction of navigable waters (generally, wharves; piers, etc.); excavation and filling-in	33 U.S.C. §401	Controls the alteration of navigable waters (i.e., waters subject to ebb and flow of the tide shoreward to the mean high water mark). Activities controlled include construction of structures such as piers, berms, and installation of pilings as well as excavation and fill. Section 10 may be applicable for any action that may obstruct or alter a navigable waterway.	No permit is required for on-site activities. However, substantive requirements might limit in-water construction activities.
Endangered Species Act	16 U.S.C. §§ 1531 et seq.	Federal agencies must ensure that actions they authorize, fund, or carry out are not likely to adversely modify or destroy critical habitat of endangered or threatened species. Actions authorized, funded, or carried out by federal agencies may not jeopardize the continued existence of endangered or threatened species as well as adversely modify or destroy their critical habitats.	If Federally listed threatened or endangered (T&E) species or their critical habitat are present on the site or utilize areas in the vicinity of the site, this requirement is potentially relevant to determination of cleanup areas/volumes, preliminary remediation goals, and determination of removal alternatives. Based on review of USFWS and NMFS maps, no critical habitat is present at the site. Based on a review of photos and aerial images of the site and lists of federal T&E species and their habitats, it is unlikely that T&E species are present at the site, although some species may be present downstream in the Houston Ship Channel vicinity. Pursuant to CERCLA 121(e) and USEPA policy, separate consultation with the U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) is not required and permits are not required. USEPA will consult with the resource agencies.
Fish and Wildlife Coordination Act	16 U.S.C. §§661 et seq., 16 U.S.C. §742a, 16 U.S.C. § 2901	Requires adequate provision for protection of fish and wildlife resources. This title has been expanded to include requests for consultation with USFWS for water resources development projects (Mueller 1980). Any modifications to rivers and channels require consultation with the USFWS, Department of Interior, and state wildlife resources agency[3]. Project-related losses (including discharge of pollutants to water bodies) may require mitigation or compensation.	Applicable to any action that controls or modifies a body of water.
Bald and Golden Eagle Protection Act	16 U.S.C. §668a-d	Makes it unlawful to take, import, export, possess, buy, sell, purchase, or barter any bald or golden eagle, nest, or egg. "Take" is defined as pursuing, hunting, shooting, poisoning, wounding, killing, capturing, trapping and collecting, molesting, or disturbing.	This requirement is potentially relevant to CERCLA activities. No readily available information suggests bald or golden eagles frequent the project area; however, a qualified biologist would perform a site visit prior to a potential remedial action to confirm that bald and golden eagles do not frequent the project area.
Migratory Bird Treaty Act	16 U.S.C. §§703-712 (implementing regulations at 50 CFR §10.12)	Makes it unlawful to take, import, export, possess, buy, sell, purchase, or barter any migratory bird. "Take" is defined as pursuing, hunting, shooting, poisoning, wounding, killing, capturing, and trapping and collecting.	This requirement is potentially relevant to CERCLA activities. No readily available information suggests migratory birds frequent the project area, and aerial photography of the site suggests no suitable nesting or stopover habitat is present; however, a qualified biologist would perform a site visit prior to a potential remedial action to confirm that migratory birds do not frequent the project area.
Coastal Zone Management Act	16 USC §§1451 et seq. (implementing regulations at 15 CFR 930)	Federal activities must be consistent with, to the maximum extent practicable, State coastal zone management programs. Federal agencies must supply the State with a consistency determination (USEPA 1989).	Patrick Bayou lies within the Coastal Zone Boundary according to the Texas Coastal Management Plan (TCMP) prepared by the General Land Office (GLO). The FS will consider whether the remedial alternatives would affect (adversely or not) the coastal zone, the lead agency is required to determine whether the activity will be consistent with the State's CZMP (USEPA 1989). More information regarding the state requirements is provided under Texas Coastal Coordination Council (TCCC) Policies for Development in Critical Areas.
FEMA (Federal Emergency Management Agency), Department of Homeland Security (Operating Regulations)	42 U.S.C. 4001 et seq. (implementing regulations at 44 CFR Chapter 1)	Prohibits alterations to river or floodplains that may increase potential for flooding.	This requirement is relevant to CERCLA activities in floodplains and in the river because the project area is within a designated flood zone. The FS will include an assessment of the potential impacts of remedial alternatives on the floodplain.

[3] Texas Parks and Wildlife Department.

Table 3-2
Potential ARAR Screening for the Patrick Bayou Superfund Site, Remedial Alternatives Technology Screening

Potential ARARs[1]	Citation	Summary	Comment
National Flood Insurance Program (NFIP) Regulations	42 U.S.C. subchapter III, §§4101 et seq.	Provides federal flood insurance to local authorities and requires that the local authorities not allow fill in the river that would cause an increase in water levels associated with floods.	A hydrologic evaluation will be performed to determine if remedial alternatives would have a significant impact on the water level during a flood.
Title 40: Protection of the Environment - Statement of Procedures on Floodplain Management and Wetlands Protection	40 CFR Part 6 App. A; Executive Orders (EO) 11988 and 11990	Requires federal agencies to conduct their activities to avoid, if possible, adverse impacts associated with the destruction or modification of wetlands and occupation or modification of floodplains. Executive Orders 11988 and 11990 require federal projects to avoid adverse effects and minimize potential harm to wetlands and within flood plains. The EO 11990 requires federal agencies to avoid to the extent possible the long and short-term adverse impacts associated with the destruction or modification of wetlands and to avoid direct or indirect support of new construction in wetlands wherever there is a practicable alternative (USEPA 1994).	This requirement is potentially relevant to disposal or treatment activities in the upland as well as any in-water facilities that might displace floodwaters. The waste pits are located within the floodway and Zone AE, or the 1% probability floodplain. Effects on the base flood, typically the 100-year or 1% probability flood, should be minimized to the maximum extent practicable (Code of Federal Regulations 1985 as amended). The agency also adopted a requirement that the substantive requirements of the Protection of Wetlands Executive Order must be met (USEPA 1994). Unavoidable impacts to wetlands must be mitigated (USEPA 1994)[4].
National Historic Preservation Act	16 U.S.C. §§ 470 et seq. (implementing regulations at 36 CFR 800)	Section 106 of this statute requires Federal agencies to consider effects of their undertakings on historic properties. Historic properties may include any district, site, building, structure, or object included in or eligible for the National Register of Historic Places (NRHP), including artifacts, records, and material remains related to such a property.	Because of the extensive disturbance to the site and minimal upland disturbance that will likely occur for the project, it is not likely that NRHP-eligible historic properties will be affected by eventual site remediation activities.
Noise Control Act	42 U.S.C. §§ 4901 et seq. (implementing regulations at 40 CFR Subchapter G §201 et seq.	Noise Control Act remains in effect but unfunded (USEPA 2010).	Noise is regulated at the state level. See Texas Penal Code under state ARARs.
Hazardous Materials Transportation Act	49 U.S.C. §§1801 et seq. (implementing regulations at 49 CFR. Subchapter C)	Establishes standards for packaging, documenting, and transporting hazardous materials.	This requirement would apply to remedial alternatives that involve transporting hazardous materials off-site for treatment or disposal.

[4] Each agency is expected to minimize the destruction, loss, or degradation of wetlands, and to preserve and enhance the natural and beneficial values of wetlands when implementing actions such as CERCLA sites (President of the United States 1977). If §404 of the Clean Water Act is considered an ARAR, then the 404(b)(1) guidelines established in a Memorandum of Understanding (MOU) between USEPA and Department of Army should be followed (USEPA 1994). When habitat is severely degraded, a mitigation ratio of 1:1 may be acceptable (USEPA 1994). However, any mitigation would be at the discretion of the agency and the USEPA may elect to orient mitigation towards “minimizing further adverse environmental impacts rather than attempting to recreate the wetlands original value on site or off site” (USEPA 1988).

Table 3-2
Potential ARAR Screening for the Patrick Bayou Superfund Site, Remedial Alternatives Technology Screening

Potential ARARs	Citation	Summary	Comment
State			
30 Texas Administrative Code (TAC) Part 1: Industrial Solid Waste and Municipal Hazardous Waste General Terms	30 TAC §§335.1 – 335.15	General Terms: Substantive requirements for the transportation of industrial solid and hazardous wastes; requirements for the location, design, construction, operation, and closure of solid waste management facilities.	Guidelines to promote the proper collection, handling, storage, processing, and disposal of industrial solid waste or municipal hazardous waste in a manner consistent with the purposes of Texas Health and Safety Code, Chapter 361. Solid nonhazardous waste provisions are applicable if material is transported to an upland disposal facility.
30 TAC Part 1: Industrial Solid Waste and Municipal Hazardous Waste: Notification	30 TAC Chapter 335 Subchapter P	Requires placement of warning signs in contaminated and hazardous areas if a determination is made by the executive director of the Texas Water Commission a potential hazard to public health and safety exists which will be eliminated or reduced by placing a warning sign on the contaminated property.	The FS will consider the need for additional warning signs and fencing as part of potential institutional controls that may be implemented as a component of the remedial alternatives.
30 TAC Part 1: Industrial Solid Waste and Municipal Hazardous Waste: Generators	30 TAC Chapter 335, Subchapter C	Standards for hazardous waste generators either disposing of waste on-site or shipping off-site with the exception of conditionally exempt small quantity generators. The definition of hazardous involves state and federal standards.	The sediment at the site are not listed hazardous waste, do not contain listed hazardous waste, and do not meet any of the characteristics of hazardous waste. Therefore, the rules for hazardous waste are neither applicable nor relevant and appropriate.
Texas Surface Water Quality Standards	30 TAC §307.4-7, 10	These state regulations provide: • General narrative criteria • Anti-degradation Policy • Numerical criteria for pollutants • Numerical and narrative criteria for water-quality related uses (e.g., human use) • Site specific criteria for Patrick Bayou	Surface water quality standards are ARARs.
Texas Water Quality: Pollutant Discharge Elimination System (TPDES)	30 TAC §279.10	These state regulations require stormwater discharge permits for either industrial discharge or construction-related discharge. The State of Texas was authorized by USEPA to administer the NPDES program in Texas on September 14, 1998 (Texas Commission on Environmental Quality 2009).	The FS will evaluate the need for a discharge permit for off-site remedial actions.
Texas Water Quality: Water Quality Certification	30 TAC §279.10	These state regulations establish procedures and criteria for applying for, processing, and reviewing state certifications under CWA, §401. It is the purpose of this chapter, consistent with the Texas Water Code and the federal CWA, to maintain the chemical, physical, and biological integrity of the state's waters.	The development and evaluation of remedial alternatives will include consideration of potential water-quality impacts, relevant to the Water Quality Certification in Texas. Although permits are not required for on-site CERCLA actions, water quality certification is relevant as part of identification of substantive state ARARs (USEPA 1988).
Texas Risk Reduction Program	30 TAC §350	Activated upon release of Chemicals of Concern (COC). The Risk Reduction Program uses a tiered approach incorporating risk assessment techniques to help focus investigations, to determine appropriate protective concentration levels for human health, and when necessary, for ecological receptors. Includes protective concentration levels.	TRRP describes separate tiered processes for establishing Protective Concentration Levels (PCL) for COCs that can remain in a medium and be protective of human and ecological receptors at the point of exposure. As the site-specific risk assessment identified potential risk only to wildlife and benthic invertebrates, ecological PCLs for the indicator chemicals will be considered in the development of remedial action levels to protect these receptors. TRRP human health PCLs are not considered TBCs given that no COCs were identified in the Baseline Human Health Risk Assessment.
Natural Resources Code, Antiquities Code of Texas	Texas Parks and Wildlife Commission Regulations 191.092-171	Requires that the Texas Historical Commission staff review any action that has the potential to disturb historic and archeological sites on public land. Actions that need review include any construction program that takes place on land owned or controlled by a state agency or a state political subdivision, such as a city or a county. Without local control, this requirement does not apply.	Disturbance of any archaeological or historic resources is unlikely due to the highly modified nature of the site and focus of action within the sediments as opposed to upland areas. Depending on the magnitude and specific boundaries of ground disturbance determined during the FS for the overall site, this ARAR may need to be re-evaluated.
Practice and Procedure, Administrative Code of Texas	13 TAC Part 2, Chapter 26	Regulations implementing the Antiquities Code of Texas. Describes criteria for evaluating archaeological sites and permit requirements for archaeological excavation.	This requirement is only applicable if an archaeological site is found.

Table 3-2
Potential ARAR Screening for the Patrick Bayou Superfund Site, Remedial Alternatives Technology Screening

Potential ARARs	Citation	Summary	Comment
State of Texas Threatened and Endangered Species Regulations	31 TAC 65.171 - 65.176	No person may take, possess, propagate, transport, export, sell or offer for sale, or ship any species of fish or wildlife listed as threatened or endangered.	No readily available information suggests endangered or threatened species in the project area. NMFS includes endangered sea turtles in Trust resources impacted by contaminated surface water and sediments likely transported from the site. The presence or absence of state T&E species will be documented for the site as part of the FS.
TCCC Policies for Development in Critical Areas	31 TAC §501.23	Dredging in critical areas is prohibited if activities have adverse effects or degradation on shellfish and/or jeopardize the continued existence of endangered species or results in an adverse effect on a coastal natural resource area (CNRA)[5]; prohibit the location of facilities in coastal natural resource areas unless adverse effects are prevented and /or no practicable alternative. Actions should not be conducted during spawning or nesting seasons or during seasonal migration periods. Specifies compensatory mitigation.	The FS will evaluate the potential effects of remedial alternatives on Coastal Natural Resource Area (CNRAs), which includes coastal wetlands (Railroad Commission of Texas n.d.).
Texas Coastal Management Plan Consistency	31 TAC, §506.12	Specifies Federal actions within the CMP boundary that may adversely affect CNRAs; specifically selection of remedial actions.	Patrick Bayou lies within the Coastal Zone Boundary (GLO TCMP). The FS will evaluate whether remedial alternatives may affect (adversely or not) the coastal zone and will provide a technical basis for the lead agency to determine whether the activity will be consistent with the State's CZMP (USEPA 1989).
Texas State Code – obstructions to navigation	Natural Resources Code § 51.302 Prohibition and Penalty	Prohibits construction or maintenance of any structure or facility on land owned by the State without an easement, lease, permit, or other instrument from the State.	The FS will evaluate whether the remedial alternatives include construction on state-owned land.
Noise Regulations	Texas Penal Code Chapter 42, Section 42.01	The Texas Penal Code regulates any noise that exceeds 85 decibels after the noise is identified as a public nuisance.	Noise abatement may be required if actions are identified as a public nuisance. Due to the isolation of the site, its location adjacent to a freeway with high volumes of traffic during normal working hours, and the industrial nature of the nearest properties, noise from construction activity associated with a potential remedial action is unlikely to constitute a public nuisance. Noise associated with truck traffic to and from the site should be considered.
Local			
Harris County Floodplain Management Permit[6]	Regulations of Harris County, Texas for Flood Plain Management	All development occurring within the floodplain of unincorporated Harris County requires a permit from Harris County; provide land use controls necessary to qualify unincorporated areas of Harris County for flood insurance under requirements of the National Flood Insurance Act of 1968, as amended, to protect human life and health (Harris County 2007).	Floodplain management is addressed under the Federal requirements for floodplains.

REFERENCES

Code of Federal Regulations, 1985. "40 CFR Appendix A to Part 6 - Statement of Procedures on Floodplain Management and Wetlands Protection." *vLex United States.* June 25, 1985 as amended. http://cfr.vlex.com/vid/appendix-6-statement-floodplain-wetlands-19781438. Harris County Flood Control District, 2007. *FEMA Floodplains Effective June 18, 2007.* Houston, TX: Harris County, TX, 2007.

[5] A CNRA is a coastal wetland, oyster reef, hard substrate reef, submerged aquatic vegetation, tidal sand, or mud flat.
[6] Harris County authorization is based upon Texas Local Government Code Section 240.901, as amended; Texas Transportation Code Sections 251.001 - 251.059 and Sections 254.001 - 254.019, as amended; the Harris County Road Law, as amended; and the Flood Control and Insurance Act, Subchapter I of Chapter 16 of the Texas Water Code, as amended.

Harris County Public Infrastructure Department, Architecture and Engineering Division (Harris County), 2007. Regulations of Harris County, Texas for Floodplain Management. As Adopted June 5, 2007. Effective June 2007. Amended November 2011. http://hcpid.org/permits/fp_regs.html. (Accessed April 13, 2012).

Mueller, Daniel H. and A. J. Smalley, 1980. *Water Resources Development Act Under the Fish and Wildlife Coordination Act.* Arlington, VA: U.S. Fish and Wildlife Service, 1980.

Texas Administrative Code. http://www.sos.state.tx.us/tac/. (Accessed April 2012).

Texas Commission on Environmental Quality. "What is the Texas Pollutant Discharge Elimination System?" *Texas Commission on Environmental Quality.* September 24, 2009. http://www.tceq.state.tx.us/permitting/water_quality/wastewater/pretreatment/tpdes_definition.html. (Accessed April 2012).

Texas Council on Environmental Quality http://www.tceq.state.tx.us/. (Accessed April 2012).

Texas General Land Office Texas Coastal Management Program Coastal Zone Boundary Map http://www.glo.texas.gov/what-we-do/caring-for-the-coast/_documents/landing-page-folder/CoastalBoundaryMap.pdf . (Accessed April 13, 2012).

Texas Parks and Wildlife Department, Wildlife Division, Diversity and Habitat Assessment Programs. County Lists of Texas' Special Species. [Harris County, updated 3/5/2010. (Accessed June 23, 2010).

Texas Natural Resources Code Title 31. Natural Resources and Conservation, Part 16. Coastal Coordination Council, Chapter 501 Rule 503.1. Coastal Management Program Boundary. h (Accessed April 13, 2012).

United States Department of Commerce Combined Coastal Management Program and Final Environmental Impact Statement for the State of Texas. Prepared by: Office of Ocean and Coastal Resource Management National Oceanic and Atmospheric Administration U.S. Department of Commerce And The State of Texas, August 1996. http://www.glo.state.tx.us/coastal/cmp/feis/CMP_FEIS_1996.pdf.

University of Houston. "On Shaky Ground: Geological Faults Threaten Houston." ScienceDaily 29 April 2008. <http://www.sciencedaily.com /releases/2008/04/080424153833.htm>.

University of Texas. Karst and pseudokarst regions of Texas. http://www.utexas.edu/tmm/sponsored_sites/tss/images/tk1.gif. (Accessed April 13, 2012).

United States Environmental Protection Agency (USEPA), 1988. *CERCLA Compliance with Other Laws Manual: Interim Final.* 1988.

USEPA, 1994. Considering Wetlands at CERCLA Sites. 1994.

USEPA, 1988. *CERCLA Compliance with Other Laws Manual: Interim Final.* EPA/540/G-89/006. August 1988.

USEPA, 2007. Clean Water Act Jurisdiction. Following the U.S. Supreme Court's Decision in Rapanos v. United States & Carabell v. United States.

USEPA, 2008. "Sole Source Aquifers." *Region 6 Water Programs.* March 18, 2008. http://www.epa.gov/region6/water/swp/ssa/maps.htm. (Accessed April 13, 2012).

USEPA, 2009. "Air Pollution Operating Permit Program Update: Key Features and Benefits." *Operating Permits.* July 10, 2009. http://www.epa.gov/air/oaqps/permits/permitupdate/brochure.html. USEPA, 2010. Does the EPA Regulate Noise? http://publicaccess.custhelp.com/cgi-bin/publicaccess.cfg/php/enduser/std_adp.php?p_faqid=1765..

USFWS, 2012. USFWS Wetland Mapper for National Inventory Map Information. Accessed online at http://www.fws.gov/wetlands/data/Mapper.html on April 13, 2012.

Table 5-1

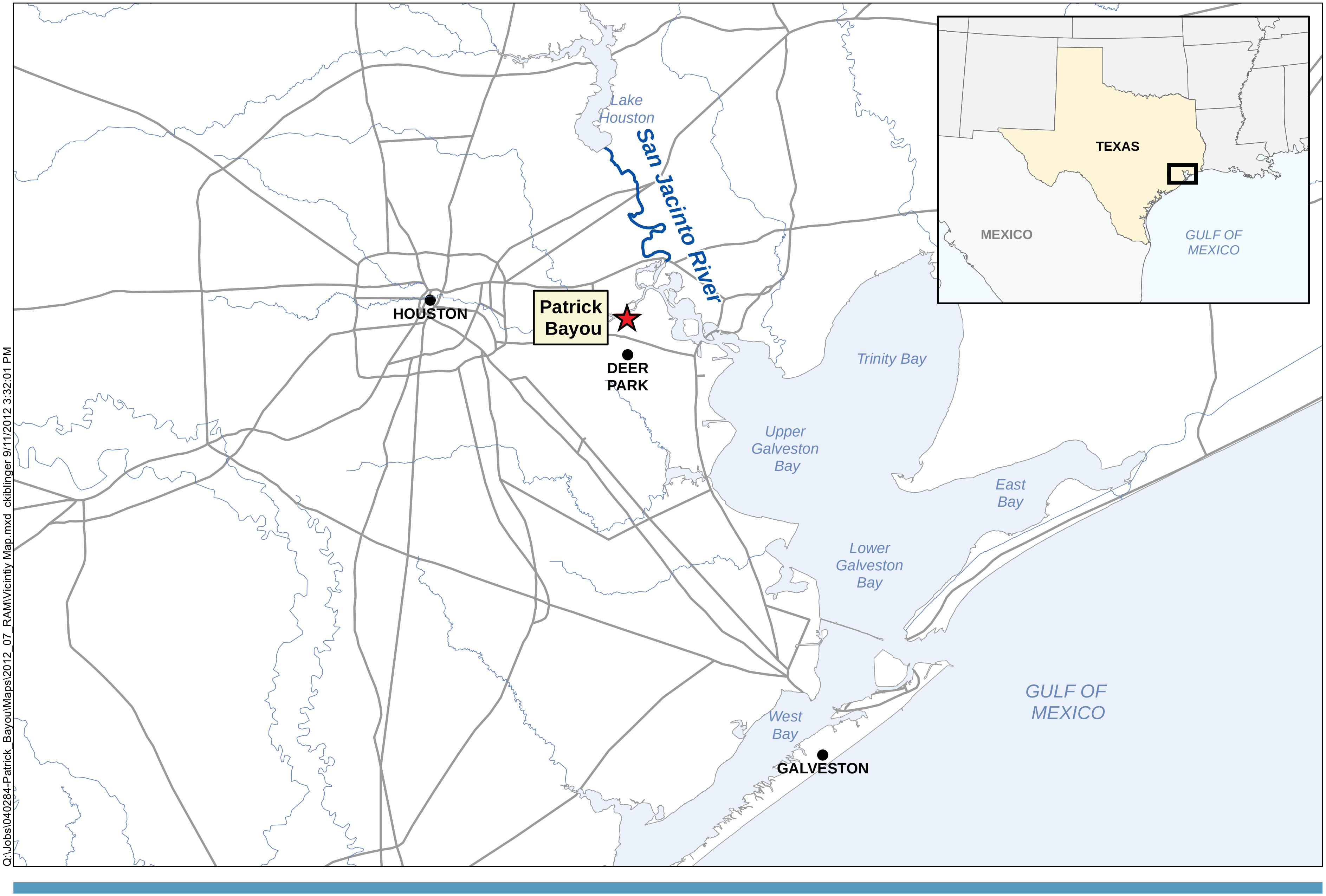
Summary of Technology Implementability Screening Results by SMA Based on Site Uses and Physical Conditions[1]

Label	Feature	Description	MNR	EMNR	In Situ Treatment	Engineered and Active Capping	Full Removal	Ex Situ Treatment[2]
NS[3]	Nearshore Area	Areas with water depths shallower than approximately 2 feet, which could constrain access for some process options	YES	YES	YES	YES	YES	YES
ST	Fixed Structure	Areas where access by water-based equipment is highly restricted and upland structures, utilities, and/or topography highly restrict access from shore.	YES	YES	YES	YES	NO	NO
AB[4]	Artifical Banks	The concrete-lined upper channel	Further Study Required	Further Study Required	NO	YES	Further Study Required	Further Study Required
NE_{100}[5]	Net Erosional	Areas considered to be net erosional in a 100-year flood based on the hydrodynamic model of the site.	Further Study Required	Further Study Required	YES	YES	YES	YES
OW[3]	Open Water Area	Areas where there is no restrictions to dredging or capping equipment.	YES	YES	YES	YES	YES	YES

Notes:

1. All screening results in this table are for draft FS purposes only, and all technologies discussed here may be implementable under specific circumstances for specific SMAs as determined in remedial design.
2. Ex situ treatment implementability is not typically controlled by the Site use and physical conditions in this table. Implementability issues related to removal before ex situ treatment are noted here.
3. NS and OW SMAs generally can support all remedial technologies. However, there may be specific process option limitations due to access constraints in NS areas. Thus, the NS SMA has been defined to facilitate more detailed consideration of implementability during the FS.
4. Specific access constraints will govern the ability to conduct remedy construction in this particularly constrained area of the Site. Access is limited. The hard bottom and debris is expected to significantly increase the potential for resuspension and water quality issues during removal. Removal of the concrete banks could have the potential to destabilize adjacent upland facilities.
5. Depending on the magnitude of erosion in a design level storm, MNR and EMNR may or may not be applicable. A more detailed understanding of recovery time frames and modeling of deposition and erosion would need to be performed in the FS if these technologies are to be proposed for NE areas.

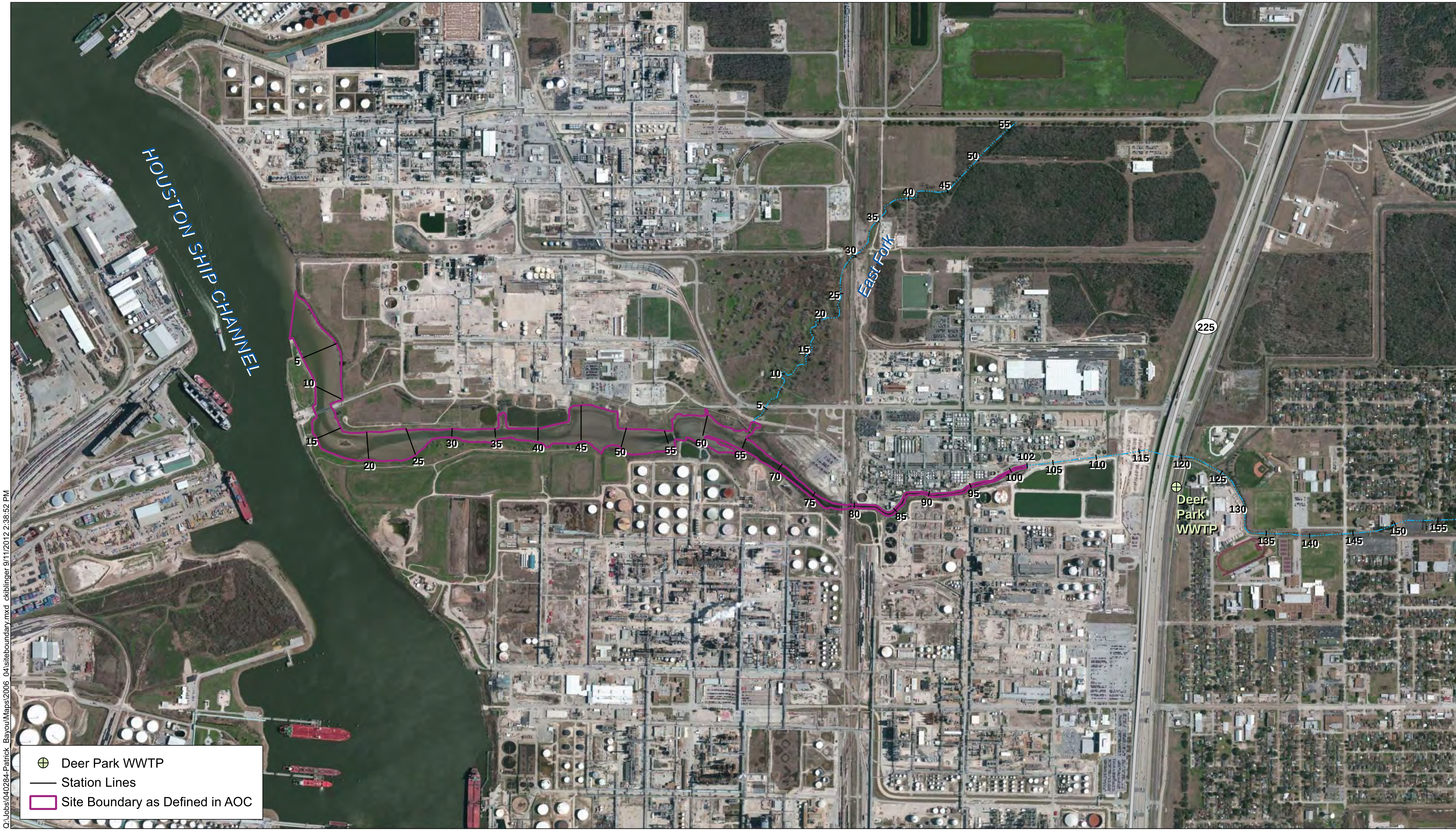
FIGURES



Q:\Jobs\040284-Patrick_Bayou\Maps\2012_07_RAM\Vicintiy Map.mxd ckiblinger 9/11/2012 3:32:01 PM

ANCHOR QEA

Figure 1-1
Vicinity Map
Patrick Bayou Remedial Alternatives Technology Screening
Patrick Bayou Superfund Site Remedial Investigation, Deer Park, Texas



Q:\Jobs\040284-Patrick_Bayou\Maps\2006_04\siteboundary.mxd ckiblinger 9/11/2012 2:38:52 PM

ANCHOR QEA

NOTES:
1. With the exception of 102, stations are placed in 500-foot intervals. Station numbers indicate length along channel in hundreds of feet.
2. Aerial imagery: Microsoft Bing Maps, copyright 2010 (accessed 9/11/2012).

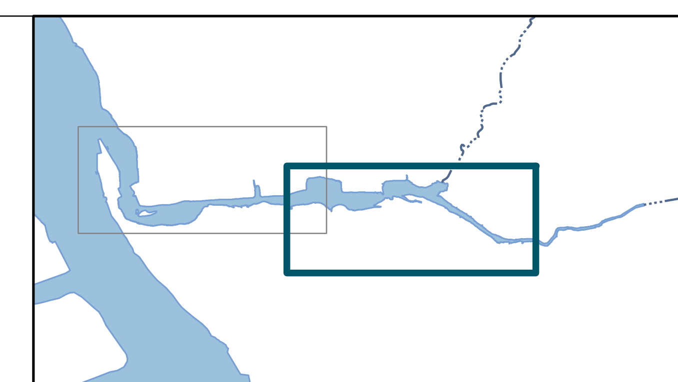
Figure 2-1
Site Boundary and Stations
Patrick Bayou Remedial Alternatives Technology Screening
Patrick Bayou Superfund Site Remedial Investigation, Deer Park, Texas

2-foot Contours
≤ -5
-4 - 0
1 - 5
6 - 10
> 10

Station Lines

NOTES:
1. Bathymetry: GBA Survey, May/June 2005.
2. Contour intervals are in 2-foot intervals referenced to the NAVD88 vertical datum.
3. Aerial imagery: Microsoft Bing Maps, copyright 2010 (accessed 9/11/2012).

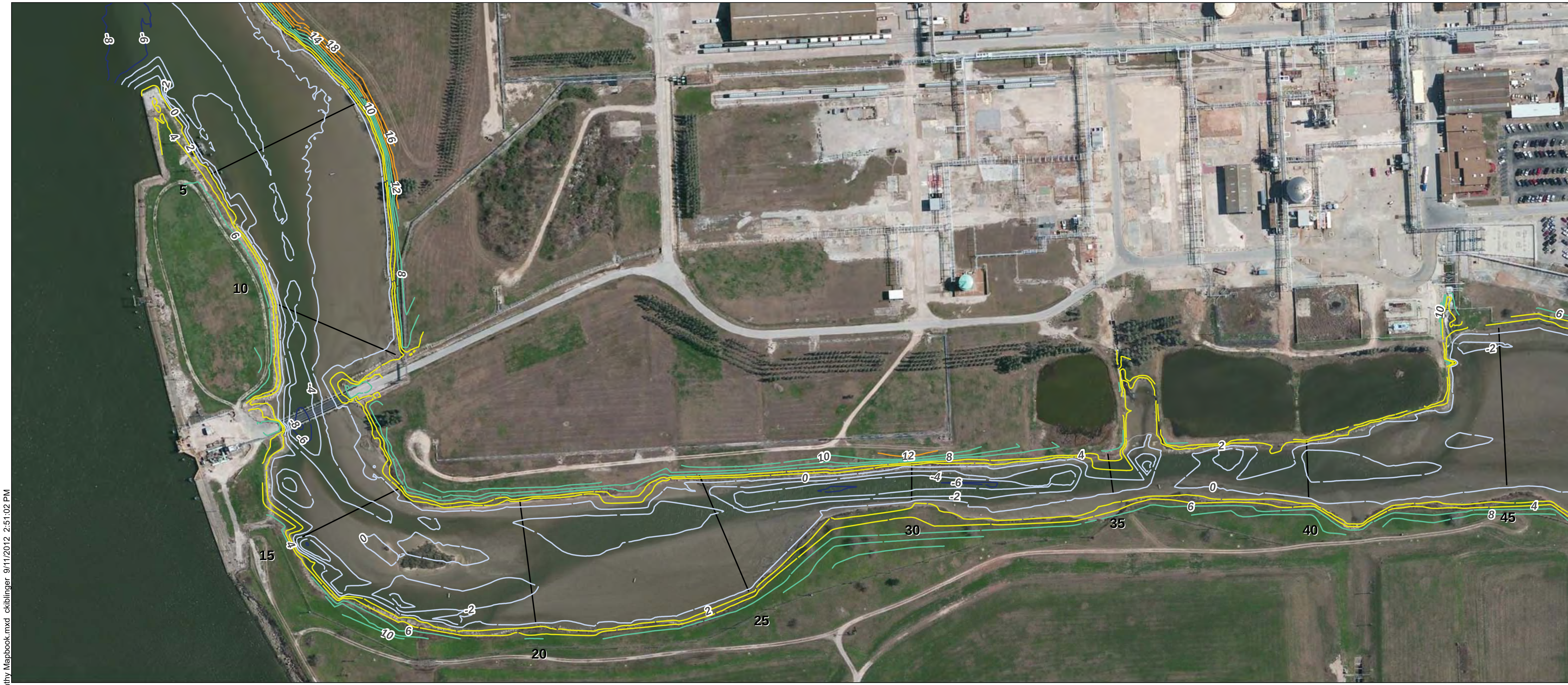
Feet
0 125 250 375 500



Q:\Jobs\040284-Patrick_Bayou\Maps\2012_07_RAM\Bathy Mapbook.mxd ckiblinger 9/11/2012 2:50:57 PM

ANCHOR QEA

Figure 2-2
Site Bathymetry - South
Patrick Bayou Remedial Alternatives Technology Screening
Patrick Bayou Superfund Site Remedial Investigation, Deer Park, Texas

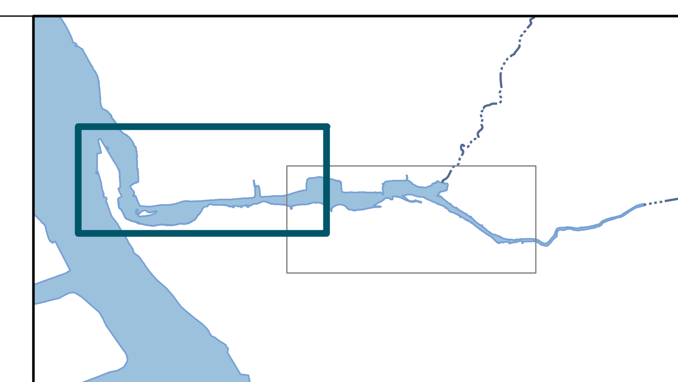


2-foot Contours
- ≤ -5
- -4 - 0
- 1 - 5
- 6 - 10
- > 10

Station Lines

NOTES:
1. Bathymetry: GBA Survey, May/June 2005.
2. Contour intervals are in 2-foot intervals referenced to the NAVD88 vertical datum.
3. Aerial imagery: Microsoft Bing Maps, copyright 2010 (accessed 9/11/2012).

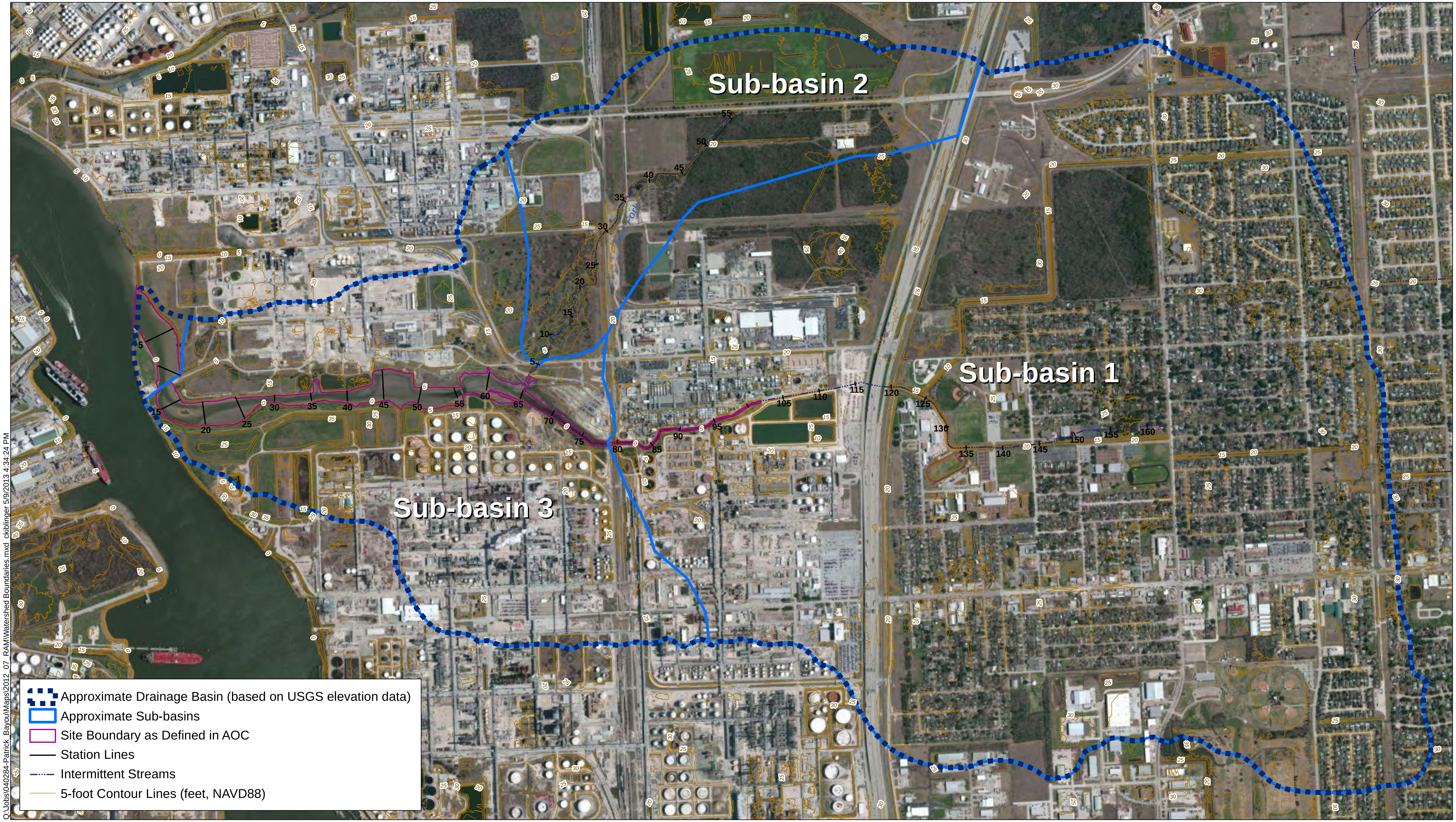
Feet
0 125 250 375 500



Q:\Jobs\040284-Patrick_Bayou\Maps\2012_07_RAM\Bathy Mapbook.mxd ckiblinger 9/11/2012 2:51:02 PM

ANCHOR QEA

Figure 2-3
Site Bathymetry - North
Patrick Bayou Remedial Alternatives Technology Screening
Patrick Bayou Superfund Site Remedial Investigation, Deer Park, Texas



ANCHOR QEA

NOTES:
1. Stations are placed in 500-foot intervals. Station numbers indicate length along channel in hundreds of feet.
2. Elevation contours: Houston-Galveston Area Council, 2008 (feet, NAVD88).
3. Note that sub-basin boundaries were determined using a different elevation contour set from that shown on this figure.

Feet
0 1,250 2,500

Figure 2-4
Watershed and Sub-basin Boundaries
Patrick Bayou Remedial Alternatives Technology Screening
Patrick Bayou Superfund Site Remedial Investigation, Deer Park, Texas

Sediment Thickness (ft)
- < 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12

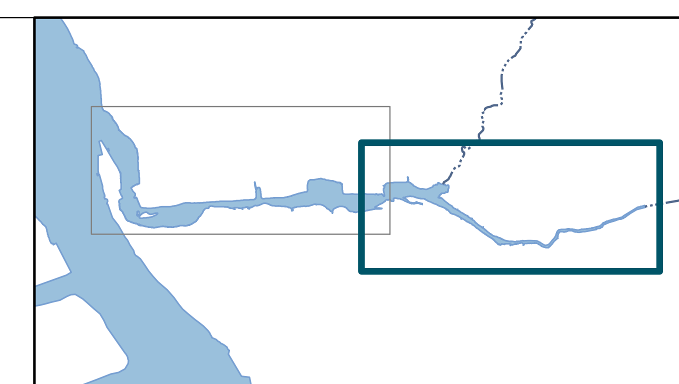
Sediment Sample Locations

Station Lines

Site Boundary as Defined in AOC

NOTES:
1. Stations are placed in 500-foot intervals. Station numbers indicate length along channel in hundreds of feet.
2. Sediment thickness data are provided by GBA (May/June 2005) and Anchor QEA (August 2011).
3. Aerial imagery: Microsoft Bing Maps, copyright 2010 (accessed 5/9/2013).

Feet
0 150 300 450 600



Q:\Jobs\040284-Patrick_Bayou\Maps\2006_04\isopach v2 Mapbook.mxd ckiblinger 5/9/2013 3:23:11 PM

ANCHOR QEA

Figure 2-5
Sediment Thickness Survey Results for Patrick Bayou - South
Patrick Bayou Remedial Alternatives Technology Screening
Patrick Bayou Superfund Site Remedial Investigation, Deer Park, Texas

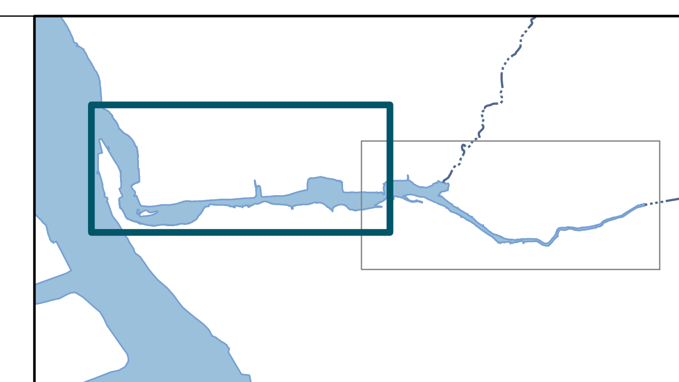
Q:\Jobs\040284-Patrick_Bayou\Maps\2006_04\isopach v2 Mapbook.mxd ckiblinger 5/7/2013 2:03:37 PM

Sediment Thickness (ft)
- < 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12

- Sample Locations
- Station Lines
- Site Boundary as Defined in AOC

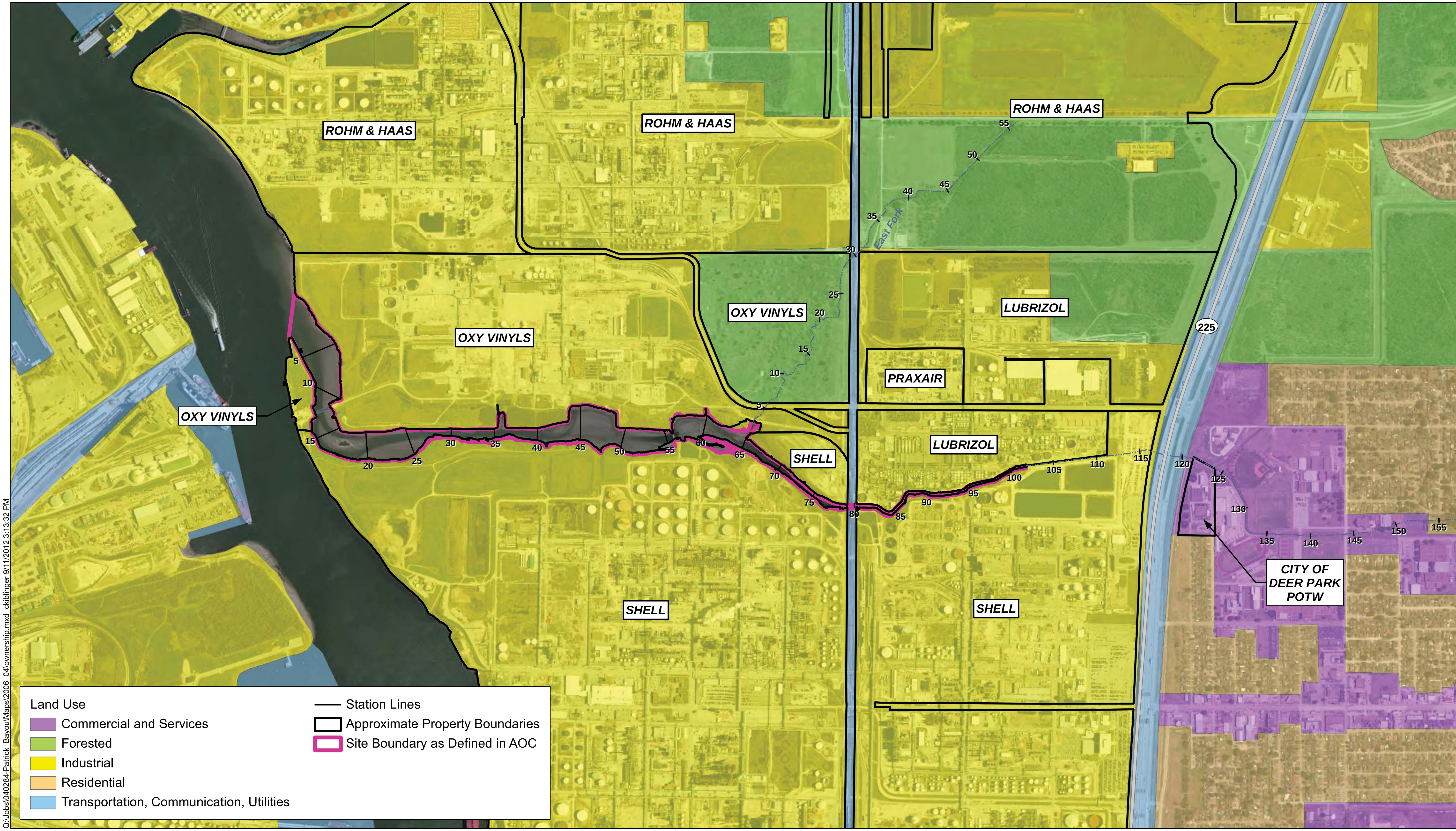
NOTES:
1. Stations are placed in 500-foot intervals. Station numbers indicate length along channel in hundreds of feet.
2. Sediment thickness data are provided by GBA (May/June 2005) and Anchor QEA (August 2011).
3. Aerial imagery: Microsoft Bing Maps, copyright 2010 (accessed 5/7/2013).

Feet
0 150 300 450 600



ANCHOR QEA

Figure 2-6
Sediment Thickness Survey Results for Patrick Bayou - North
Patrick Bayou Remedial Alternatives Technology Screening
Patrick Bayou Superfund Site Remedial Investigation, Deer Park, Texas

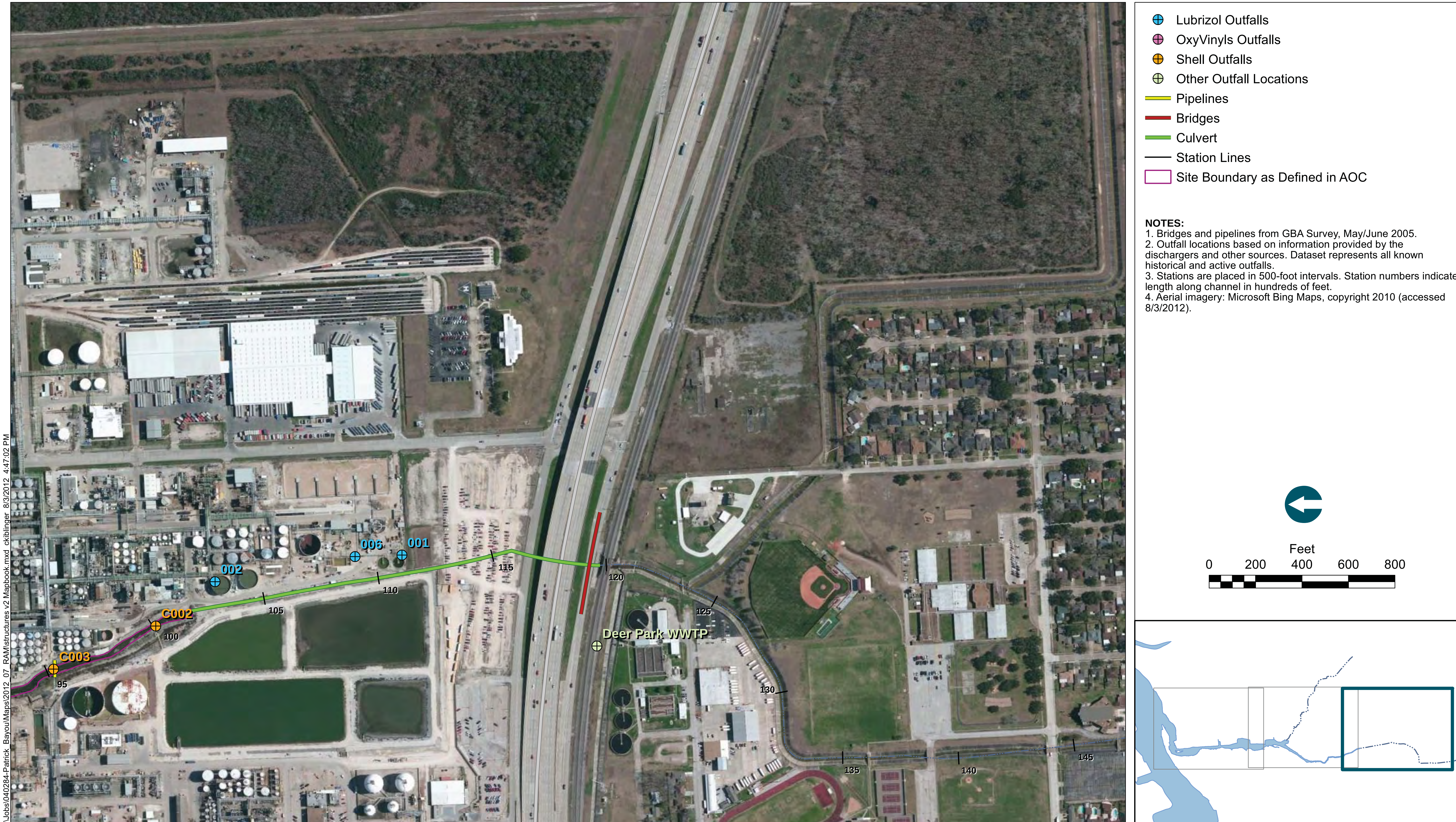


Q:\Jobs\040284-Patrick_Bayou\Maps\2006_04\ownership.mxd ckiblinger 9/11/2012 3:13:32 PM

NOTES:
1. Property Information from Harris County Appraisal District (HCAD).
2. Land use data obtained from Texas Natural Resources Information System (TNRIS) and modified using USGS orthoimagery. It is a very cursory interpretation, and should be used as a guide only.
3. Stations are placed in 500-foot intervals. Station numbers indicate length along channel in hundreds of feet.
4. Aerial imagery: Microsoft Bing Maps, copyright 2010 (accessed 9/11/2012).

ANCHOR QEA

Figure 2-7
Property Ownership
Patrick Bayou Remedial Alternatives Technology Screening
Patrick Bayou Superfund Site Remedial Investigation, Deer Park, Texas



Q:\Jobs\040284-Patrick_Bayou\Maps\2012_07_RAM\structures v2 Mapbook.mxd ckiblinger 8/3/2012 4:47:02 PM

ANCHOR QEA

Figure 2-8
Site Map Showing Structures - South
Patrick Bayou Remedial Alternatives Technology Screening
Patrick Bayou Superfund Site Remedial Investigation, Deer Park, Texas

NOTES:
1. Bridges and pipelines from GBA Survey, May/June 2005.
2. Outfall locations based on information provided by the dischargers and other sources. Dataset represents all known historical and active outfalls.
3. Stations are placed in 500-foot intervals. Station numbers indicate length along channel in hundreds of feet.
4. Aerial imagery: Microsoft Bing Maps, copyright 2010 (accessed 2/19/2013).

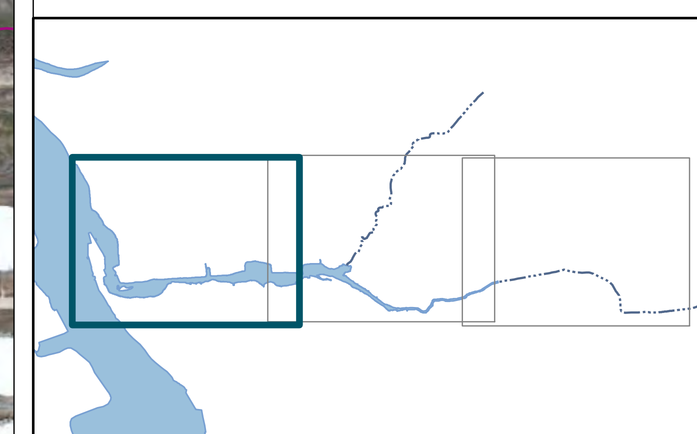
ANCHOR QEA

Figure 2-9
Site Map Showing Structures - Central
Patrick Bayou Remedial Alternatives Technology Screening
Patrick Bayou Superfund Site Remedial Investigation, Deer Park, Texas

Lubrizol Outfalls
OxyVinyls Outfalls
Shell Outfalls
Other Outfall Locations
Pipelines
Bridges
Culvert
Station Lines
Site Boundary as Defined in AOC

NOTES:
1. Bridges and pipelines from GBA Survey, May/June 2005.
2. Outfall locations based on information provided by the dischargers and other sources. Dataset represents all known historical and active outfalls.
3. Stations are placed in 500-foot intervals. Station numbers indicate length along channel in hundreds of feet.
4. Aerial imagery: Microsoft Bing Maps, copyright 2010 (accessed 2/5/2013).

Feet
0 200 400 600 800



ANCHOR QEA

Figure 2-10
Site Map Showing Structures - North
Patrick Bayou Remedial Alternatives Technology Screening
Patrick Bayou Superfund Site Remedial Investigation, Deer Park, Texas

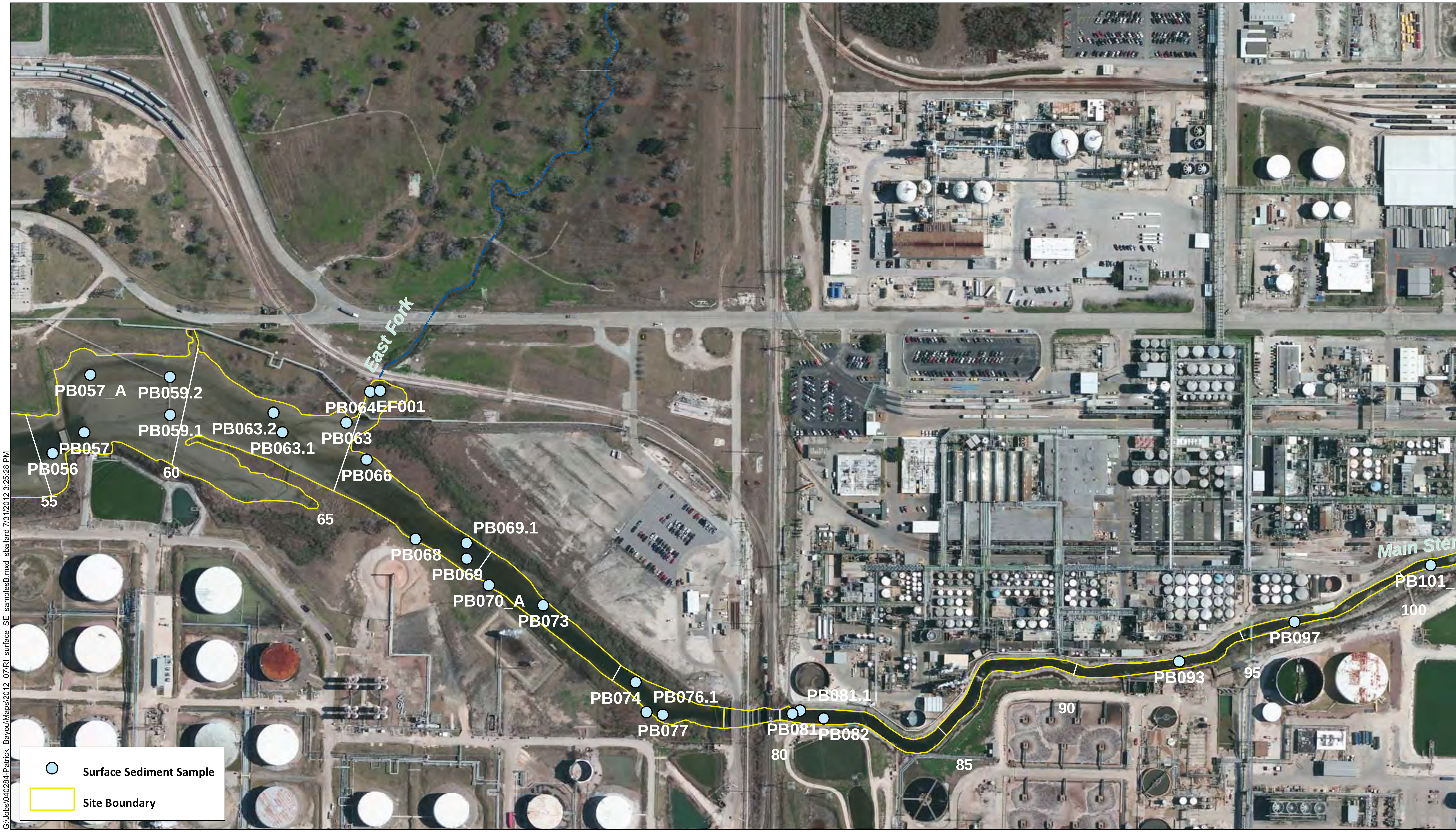
G:\Jobs\040284-Patrick_Bayou\Maps\2012_07\RI_surface_SE_samplesA.mxd sballard 7/31/2012 3:22:20 PM

ANCHOR QEA

NOTES:
1. Stations are placed in 500-foot intervals. Station numbers indicate length along channel in hundreds of feet.
2. Aerial Imagery: Microsoft Bing Maps, Copyright 2010 (accessed 07/19/2012)

Feet
0 130 260 390 520

Figure 2-11
Surface Sediment Sample Locations (PB-050 to HSC)
Patrick Bayou Remedial Alternatives Technology Screening
Patrick Bayou Superfund Site Remedial Investigation, Deer Park, Texas



ANCHOR QEA

NOTES:
1. Stations are placed in 500-foot intervals. Station numbers indicate length along channel in hundreds of feet.
2. Aerial Imagery: Microsoft Bing Maps, Copyright 2010 (accessed 07/19/2012)

Feet
0 130 260 390 520

Figure 2-12
Surface Sediment Sample Locations (PB-102 to PB-055)
Patrick Bayou Remedial Alternatives Technology Screening
Patrick Bayou Superfund Site Remedial Investigation, Deer Park, Texas

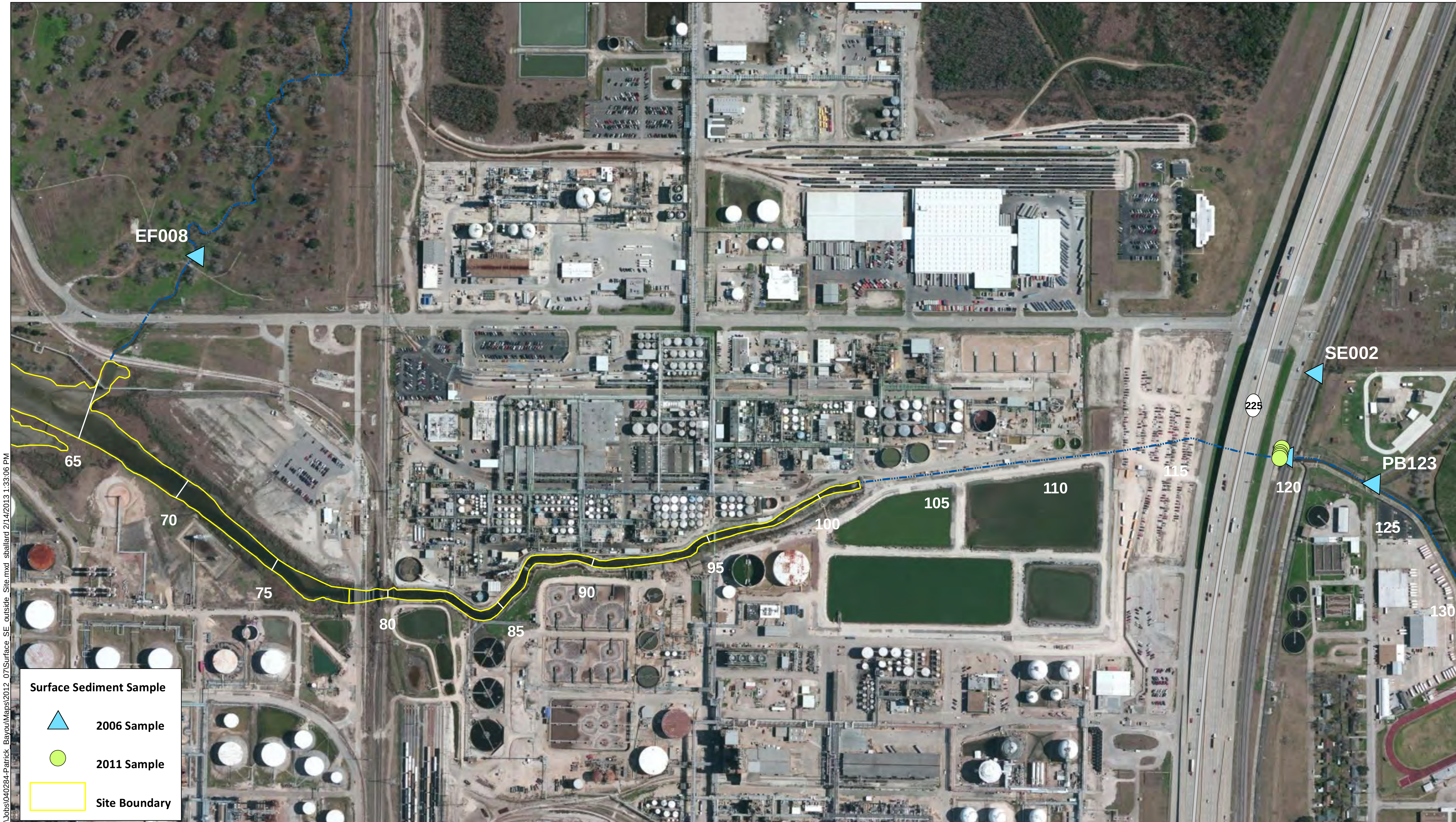
Q:\Jobs\040284-Patrick_Bayou\Maps\2012_05\RI Surface Data for RATS.mxd ckiblinger 2/13/2013 4:31:35 PM

ANCHOR QEA

NOTES:
Aerial imagery: Microsoft Bing Maps, copyright 2010 (accessed 2/13/2013).

Feet
0 300 600 900 1,200

Figure 2-13
Surface Sediment Concentration of Total PCBs
Patrick Bayou Remedial Alternatives Technology Screening
Patrick Bayou Superfund Site Remedial Investigation, Deer Park, Texas

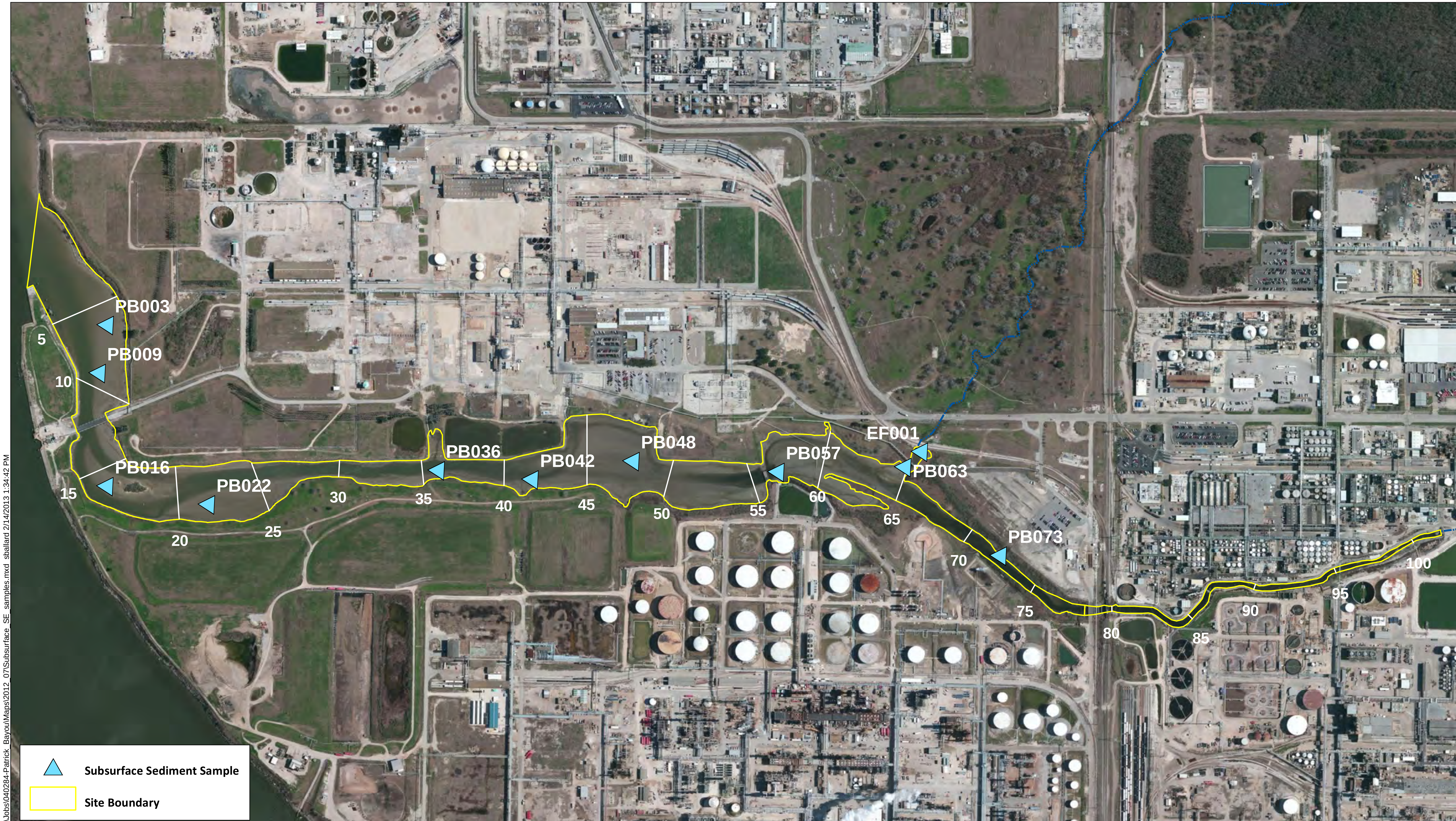


NOTES:
1. Sample interval for EF008, SE002, PB119 and PB123 is 0 to 2 cm. Sample interval for PB119.1 is 0 to 30 cm.
2. Stations are placed in 500-foot intervals. Station numbers indicate length along channel in hundreds of feet.
3. Aerial Imagery: Microsoft Bing Maps, Copyright 2010 (accessed 07/19/2012)

Feet
0 200 400 600 800

ANCHOR QEA

Figure 2-14
Surface Sediment IC Concentrations Upstream of the Site
Patrick Bayou Remedial Alternatives Technology Screening
Patrick Bayou Superfund Site Remedial Investigation, Deer Park, Texas



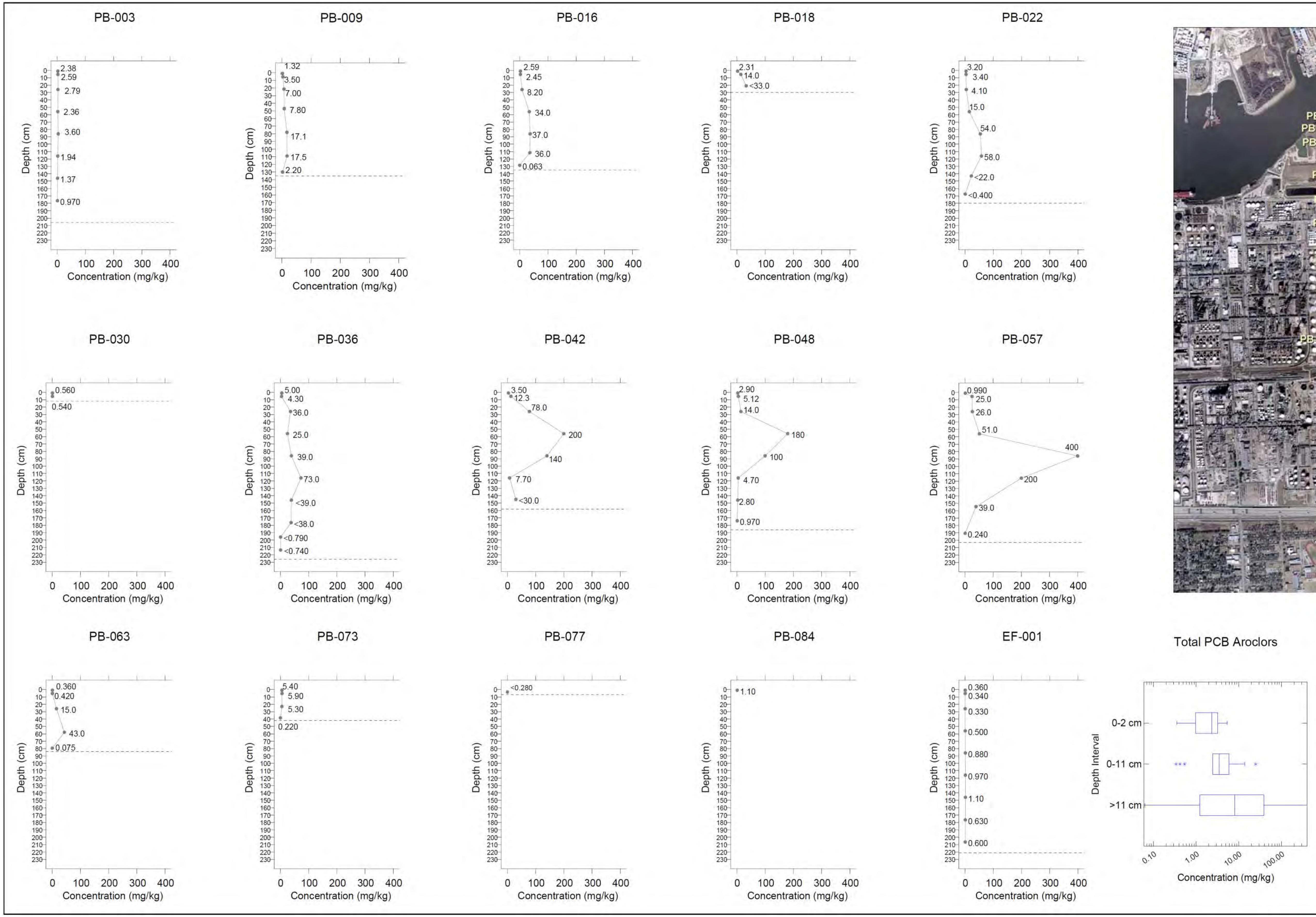
G:\Jobs\040284-Patrick_Bayou\Maps\2012_07\Subsurface_SE_samples.mxd sballard 2/14/2013 1:34:42 PM

ANCHOR QEA

NOTES:
1. Stations are placed in 500-foot intervals. Station numbers indicate length along channel in hundreds of feet.
2. Aerial Imagery: Microsoft Bing Maps, Copyright 2010 (accessed 7/19/2012)

Feet
0 280 560 840 1,120

Figure 2-15
Subsurface Sediment Sample Locations
Patrick Bayou Remedial Alternatives Technology Screening
Patrick Bayou Superfund Site Remedial Investigation, Deer Park, Texas



Notes:
Stations PB077, PB084, and PB094 not illustrated; only one depth interval collected at these stations.

Approximate core depth is indicated on each graphic by a dashed line.

< = Non-detects.

Interpretation of box plots:
The center line in the box represents the median value (50th percentile)

The box edges represent the first and third quartiles (25th and 75th percentiles). The difference between the first and third quartiles represents the H-spread or interquartile range and describes the variability in the data.

The whiskers show the range of observed values that fall within 1.5 times the interquartile range.

Values outside the whiskers are plotted with asterisks or circles. Circles represent values more than 3 times the interquartile range.

ANCHOR QEA

Figure 2-16
Vertical Distribution of Total PCB Aroclors in Patrick Bayou
Patrick Bayou Remedial Alternatives Technology Screening
Patrick Bayou Superfund Site

Q:\Jobs\040284-Patrick_Bayou\Maps\2012_04\SMAs and NSR.mxd ckiblinger 2/5/2013 10:29:37 AM

ANCHOR QEA

NOTES:
1. Net erosional areas are based on a modeled 100-year flow event.
2. Aerial imagery: Microsoft Bing Maps, copyright 2010 (accessed 2/5/2013).

Feet
0 275 550 825 1,100

Figure 3-1
Sediment Management Area Designations
Patrick Bayou Remedial Alternatives Technology Screening
Patrick Bayou Superfund Site Remedial Investigation, Deer Park, Texas

APPENDIX A
TREATMENT TECHNOLOGY REVIEW

TABLE OF CONTENTS

List of Tables

List of Figures

LIST OF ACRONYMS AND ABBREVIATIONS

AC	activated carbon
AOC	Administrative Order on Consent
APEG/KPEG	Alkaline/Potassium Polyethylene Glycolate
ARAR	Applicable or Relevant and Appropriate Requirement
As	Arsenic
BCD	base catalyzed decomposition
BMP	Best Management Practice
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cf	cubic foot
CFR	Code of Federal Regulations
cm	centimeter
COPC	chemical of potential concern
cy	cubic yard
DC	direct current
FRTR	Federal Remediation Technologies Roundtable
FS	Feasibility Study
GAC	granular activated carbon
Hg	mercury
IC	indicator chemical
IPTD	in pile thermal desorption
ISTD	in-situ thermal desorption
JDG	Patrick Bayou Joint Defense Group
King of Prussia	King of Prussia Technical Corporation
KWh	kilowatt-hour
lb	pound
m	meter
MeHg	methylmercury
mg/g	milligrams to grams
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
PAC	powdered activated carbon
PAH	polycyclic aromatic hydrocarbon

Parsons	Parsons Chemical/ETM Enterprises
PCB	polychlorinated biphenyl
PEG	polyethylene glycol
PIC	products of incomplete combustion
PSCR	Preliminary Site Characterization Report
RAO	Remedial Action Objective
RI/FS	Remedial Investigation/Feasibility Study
S/S	Solidification/Stabilization
SET	Solvated Electron Technology™
sf	square foot
Site	Patrick Bayou Superfund Site
SITE	Superfund Innovative Technology Evaluation
SOW	Statement of Work
SPAWAR	Space and Naval Warfare Systems Command
SSC Pacific	SPAWAR Systems Center Pacific
SVOC	semivolatile organic compound
SWAC	surface weighted average concentration
TCE	trichloroethene
TCLP	Toxicity Characteristic Leaching Procedure
USACE	U.S. Army Corps of Engineers
US-ACE	U.S. Army Environmental Center
USEPA	U.S. Environmental Protection Agency
UV	ultraviolet
VOCs	volatile organic compounds
μg/kg	micrograms per kilogram

EXECUTIVE SUMMARY

This work was performed as part of the *Feasibility Study* (FS) for the Patrick Bayou Superfund Site (Site) being conducted by the Patrick Bayou Joint Defense Group (JDG) in response to an Administrative Order on Consent (AOC) and Settlement Agreement with the with U.S. Environmental Protection Agency (USEPA), dated January 31, 2006. In accordance with Task V – Treatability Studies of the Statement of Work (SOW) for the *Remedial Investigation/Feasibility Study* (RI/FS), this document includes a literature survey of existing treatment technologies applicable for contaminated sediments.

Purpose

This draft *Treatment Technology Review* describes the applicable technologies, including innovative technologies that have been identified for further evaluation in the Remedial Alternatives Technology Screening developed as part of the FS for the Site. This document is a preliminary screening of treatment technologies reviewed for consideration in the development of remedial alternatives, which is discussed in the *Draft Remedial Alternatives Technology Screening* (Anchor QEA, 2013). Treatment technologies that are deemed inapplicable to the Site based on the screening results presented in Section 3 are not carried forward for further evaluation in the *Remedial Alternatives Technology Screening* (Anchor QEA 2013).

Site Chemicals of Potential Concern

As part of the *Final Baseline Ecological Risk Assessment Work Plan* (Anchor QEA 2011), the existing list of site-specific chemicals of potential concern (COPC) was refined so that a focused list of indicator chemicals (IC) could be determined to characterize risk. The draft *Baseline Ecological Risk Assessment Report* (Anchor QEA 2012b) identifies polychlorinated biphenyls (PCBs) as the primary risk driver for the Site. Based on the evaluation and discussion in the *Remedial Alternatives Technology Screening* (Anchor QEA 2013), PCBs are identified as the IC for further evaluation in the development of remedial alternatives in the FS; however, should the sediment be removed, other chemicals (e.g., lead) are present at the Site that may require additional treatment.

Review of Treatment Methods

This document is a preliminary screening of treatment technologies reviewed for consideration in the development of remedial alternatives. A broad range of remedial treatment technologies are reviewed and screened based on the short- and long-term aspects, as applicable, of three criteria: effectiveness, implementability, and cost, which are described in the National Contingency Plan, Code of Federal Regulations (CFR), Title 40, Part 300.430(e)(7). Certain technologies were retained as potentially applicable to the Site and carried into the development of remedial alternatives in the *Remedial Alternatives Technology Screening* (Anchor QEA 2013), while other treatment technologies were assessed as inapplicable to the Site and removed from further evaluation.

Summary and Conclusions

Treatment technologies that are potentially applicable to the sediments at the Site have passed the initial screening presented in Section 3 of this document. Those that are carried forward for further evaluation in the *Remedial Alternatives Technology Screening* (Anchor QEA 2013) are:

- Adsorbent Technologies
- Solidification/Stabilization (S/S)
- Sediment Washing
- Incineration
- Thermal Desorption

Additionally, several of these technologies require implementation ex-situ. To this end, Section 4 presents a hypothetical removal scenario for the Site. The unit costs for ex-situ treatment options are then applied to the hypothetical cost for removal. Specific means and methods for sediment removal and disposal options are presented in the *Remedial Alternatives Technology Screening* (Anchor QEA 2013).

1 INTRODUCTION

This work was performed as part of the *Feasibility Study* (FS) for the Patrick Bayou Superfund Site (Site) being conducted by the Patrick Bayou Joint Defense Group (JDG) in response to an Administrative Order on Consent (AOC) and Settlement Agreement with the with U.S. Environmental Protection Agency (USEPA), dated January 31, 2006. In accordance with Task V – Treatability Studies of the Statement of Work (SOW) for the *Remedial Investigation/Feasibility Study* (RI/FS), this document includes a literature survey of existing treatment technologies applicable for contaminated sediments.

1.1 Purpose

This document is a preliminary screening of treatment technologies reviewed for consideration in the development of remedial alternatives, which is discussed in the *Draft Remedial Alternatives Technology Screening* (Anchor QEA 2013). Treatment technologies that are deemed inapplicable to the Site based on the screening results presented in Section 3 are not carried forward for further evaluation in the *Remedial Alternatives Technology Screening* (Anchor QEA 2013). The screening of these technologies was performed as described in the National Contingency Plan, Code of Federal Regulations (CFR), Title 40, Part 300.430(e)(7), the *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (USEPA 1988), *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study* (USEPA and U.S. Army Corps of Engineers [USACE] 2000), and related guidance documents.

This document does not contain an evaluation of remedial alternatives for the Site. The evaluation of remedial alternatives is the subject of the FS. Rather, the purpose of this document is to identify treatment technologies that are potentially applicable as part of a remedy for the Site and review currently available information about each treatment technology to determine whether the available information is sufficient for the needs of the FS. The FS will provide an evaluation of remedial alternatives that incorporates both treatment and nontreatment technologies to mitigate threats to human health and the environment from the Site.

The FS will require sufficient information about the short- and long-term effectiveness, implementability, and cost of each treatment technology to evaluate the relative cost effectiveness of the remedial alternatives. Additional information on treatment technologies may be needed for application of the method, such as operational requirements and certain performance metrics. This type of detailed information may be obtained from treatability studies during the design phase, after the remedy is selected and may not be needed for the FS evaluation.

Candidate technologies are identified in this document as inapplicable to the Site (with the rationale provided), potentially applicable with sufficient information available to evaluate in the FS, or potentially applicable with additional information required to complete the FS evaluation. As stated in the SOW, and as appropriate, this document would only recommend the performance of treatability tests for technologies that fall into the third category (potentially applicable, but with insufficient information available to evaluate in the FS).

The following sections present information concerning available treatment methods and their applicability to the Site. This evaluation provides a review of technologies available for the treatment of sediment containing Site chemicals of potential concern (COPCs). Some of the methods described in this document are not supported with unit cost and other operational information derived from full-scale field implementation. Moreover, the cost information (if available) of laboratory and pilot-scale model tests more than likely would not translate dollar-for-dollar to actual full-scale remediation efforts. Potential treatment methods that are still in the research stage might display success in the laboratory or in pilot-scale tests, but may not reliably indicate the effectiveness of the method in full-scale operations.

2 SITE CHEMICALS OF POTENTIAL CONCERN

As discussed in Section 2.3 of the *Draft Remedial Alternatives Technology Screening* (Anchor QEA 2013), the indicator chemical (IC) for the Site is polychlorinated biphenyls (PCBs). Additional COPCs that have been considered in screening treatment technologies for the site include bis(2-ethylhexyl) phthalate, polycyclic aromatic hydrocarbons (PAHs), and lead. PCBs are generally good indicators of potential treatment effectiveness. Destructive treatment methods (e.g., incineration, biological treatment) that are effective for PCBs are likely to be effective for treatment of other organic constituents. Such treatment, however, may not successfully remove metals or reduce their toxicity or mobility. If significant concentrations of metals are present, additional treatment, such as solidification/stabilization (S/S), may be necessary to address disposal standards. By comparison, immobilization and separation treatment methods are generally at least as effective for metals as for organic constituents and may be less effective for some more water soluble or volatile organic constituents. Such constituents are not COPCs for this Site. The effectiveness of potential treatment methods is discussed in the following section.

3 REVIEW OF TREATMENT METHODS

This section presents a review and evaluation of specific treatment technologies applicable to the principal Site COPCs discussed in the previous section.

The purpose of this evaluation was to identify treatment technologies that may be applicable to one or more remedial alternatives at the Site. This evaluation also assessed whether treatability testing is needed prior to development of the FS. Potentially applicable treatment technologies emerging from this evaluation but requiring treatability testing are to be included in the FS evaluation of remedial alternatives. The purpose of the FS is to then further screen remedial alternatives which implement the treatment technologies.

Treatment technologies were assessed based on the availability of sufficient information for future incorporation into the FS. The outcome of this evaluation identified each of the potential technologies as falling in one of the following categories:

- Inapplicable to the remedial action for the Site; not to be included in the FS (no treatability testing).
- Potentially applicable, sufficient information for the remedial action to be included and evaluated in the FS (no treatability testing).
- Potentially applicable, additional information required for the remedial action to be included and evaluated in the FS (treatability testing required).

The development and screening of treatment technologies for incorporation into remedial alternatives followed the standards described in 40 CFR 300.430 (e)(7). Each of the potentially available technologies was evaluated to the extent sufficient information was available considering three criteria: (i) short- and long-term effectiveness; (ii) implementability; and (iii) cost. These evaluation components will be included, along with the other Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) nine criteria evaluation components, in development of remedial alternatives in the FS.

The effectiveness evaluation considers the applicability of each technology to treat the COPCs. Multiple factors are considered, including the ability of the treatment method to efficiently remove or immobilize the COPCs; the demonstrated short- and long-term performance of the technology in this efficiency; and the inherent physical characteristics and various confines of the Site. As discussed in the *Remedial Alternatives Technology Screening* (Anchor QEA 2013), sustainability will be incorporated into the development of remedial alternatives. Per the Region 6 Clean and Green Policy (USEPA 2009), the evaluation of long- and short-term effectiveness will favor alternatives that achieve Remedial Action Objectives (RAO) with less environmental impact. This review of technology sustainability will be presented in the FS as part of the detailed evaluation.

The implementability evaluation focuses on the technical feasibility and commercial availability of each technology and administrative feasibility of implementing the technology (e.g., the ability to obtain regulatory approvals and site access).

The cost evaluation considers the unit cost to treat contaminated materials if a treatment technology is to be implemented. Cost evaluation of treatment processes includes the major stages and components of treatment implementation (e.g., construction, operation, and maintenance). Current cost information for these treatment technologies was collected by contacting vendors and reviewing recently completed projects where such information was available.

A complete description of any remedial alternative, particularly one that includes ex-situ treatment, such as incineration or chemical dehalogenation, would require many other components (e.g., dredging, decontamination, stabilization, and transportation) that will be described in the FS. Order-of-magnitude estimates for several removal and disposal options are provided in the *Draft Remedial Alternatives Technology Screening* (Anchor QEA 2013). The costs for these additional components are not intended to represent complete pricing for any of the remedial alternatives listed; rather, the development of these cost estimates is intended solely as an order-of-magnitude comparison among technologies included in these documents.

Treatment technologies are fundamentally implemented as either in-situ or ex-situ with respect to the contaminated sediment. Ex-situ treatment technologies assume the excavation or dredging of contaminated material prior to any treatment operating either on-Site or off-

Site. The removal of contaminated sediments from the Site effectively reduces the risk for future long-term exposure; however, a previous study (Reible et al. 2003) showed that the removal of PCB-contaminated sediments from a waterway would not be as effective as in-situ capping and management for reducing the surface weighted average concentration (SWAC) over a 100-year period. As a result, any ex-situ technology must consider the effects of removal efforts; additionally, the extent of the contaminated sediments should also be considered before identifying an ex-situ remedy.

The in-situ and ex-situ treatment technologies evaluated in this document can be organized into five technology types:

1. Containment and Immobilization
   - Adsorbent Technologies
   - S/S
2. Separation and Extraction
   - Washing
   - Electrokinetics
3. Thermal Destruction and Immobilization
   - Incineration
   - Thermal Desorption
   - Vitrification
4. Chemical Destruction and Immobilization
   - Dehalogenation
   - Photolysis
5. Biological Treatment
   - Microbial Dechlorination

3.1 Containment and Immobilization

3.1.1 Adsorbent Technologies

Adsorbent technologies have been applied to sites contaminated with persistent organic pollutants to reduce their presence in the surface water, thereby decreasing the likelihood for bioaccumulation. As discussed in this section, adsorbent technologies are applicable to sites with submerged contaminated sediments and may be added directly to contaminated sediment or as a component of a sediment cap. PCBs have low solubility in water and partition strongly to organic carbon, making these chemicals particularly amenable to treatment with adsorbents.

Two adsorptive materials, organoclay and activated carbon (AC), have been well demonstrated for removing organic compounds from water. Both materials have been effectively used as amendments to contaminated sediment or as amendments to granular caps. The mechanism by which each of these amendments removes contaminants from water differs. AC is particularly well suited to removing trace amounts of contaminants from water because of the very large number of active adsorption sites on the surface of the material. The activation process creates micropores with very large active surface areas on a unit mass or volume of AC (125 acres of active surface per pound of AC[1]). AC is susceptible to fouling in mixtures of water and oil because the oil can coat granules or particles of AC, blocking the entrances of the micropores, rendering much of the surface area unavailable for the adsorption of aqueous contaminants. For this reason, AC is poorly suited to removing organic contaminants from water if an oil phase is present, as the oil quickly coats, or fouls, the AC rendering it ineffective. Organoclay is produced from bentonite clay modified with quaternary amines. The nitrogen in the amine reacts with the clay mineral, and the organic ends of the amine molecules attract organic contaminants. Organoclay is less subject to fouling than AC in the presence of nonaqueous-phase liquids. Additionally, this material can be modified to provide adsorptive capacity for certain metals such as mercury (Hg) and Arsenic (As).

Manufacturers of the amendment materials provide laboratory results and technical data sheets for their products. This information clarifies the ability and applicability of a certain

[1] http://www.calgoncarbon.com/carbon_products/faqs.html

material to a given design. However, pre-design testing is required to establish actual removal efficiency values for a project. These materials may be applied in bulk form to the Site sediments, coated on the exterior of aggregate material for placement atop the sediments, amended to a geotextile mat and placed atop the sediments, or amended to cap materials (e.g., sand) and placed atop the sediments. All of these methods have been implemented successfully on sediment projects.

Testing information for the performance of AC and organoclay to remove PCBs, specifically Aroclor 1260, from water is provided by Alther (2004). It should be noted that the Aroclor 1260 used in the experiment had a water solubility of 0.0027 milligrams per liter (mg/L). Mini-column tests with spiked water samples were performed for three types of adsorbent amendments: organoclay blended with anthracite (70 percent and 30 percent, respectively), organoclay, and bituminous AC. Results are presented as the sorbent loading at breakthrough milligrams to grams (mg/g) for each amendment and indicate that both materials are capable of immobilizing Aroclor 1260 in water.

Luthy et al. (2009) were responsible for field-testing the effects of AC when added to sediments in-situ. The study sought to affirm the validity of the AC treatment method and provide a field-scale test to assess the efficacy of this technology. The site chosen for the study was Hunters Point Shipyard in San Francisco, California, which was utilized from 1945 to 1974 by the U.S. Navy for ship maintenance and repair. For this remediation effort, AC was added to the upper 1 foot of sediments using two methods:

1. Mixing and tilling using Aquamog with rotovator attachment from Aquatic Environments, Inc.
2. Slurry injection using Compass Environmental, Inc. patented technology.

The tests showed that amending PCB-contaminated sediment with AC would reduce the bioaccumulation of PCBs in a target species (bent-nosed clam; *Macoma nasuta*), reduce the PCB porewater concentration, and reduce the PCB-sediment desorption rate. The bioaccumulation decreased 30 to 50 percent in the target species, and the porewater concentrations were reduced 50 to 70 percent as a result of the AC amendment. In the laboratory setting, under more frequent mixing of the contaminated sediment with the AC amendment, samples displayed reductions of PCB partitioning greater than 95 percent.

As part of a pilot study in the Anacostia River documented by McDonough et al. (2007), a coke amended geotextile layer was placed atop a test area of contaminated sediments. Among other constituents present in the sediments, PCBs were present at concentrations ranging from 25 to 2,400 micrograms per kilogram (μg/kg). PAHs and heavy metals were also detected in the affected sediments. The geotextile mat layer was installed using a crane with clamshell bucket; diver assistance was also necessary to observe that the required overlap of approximately 1 foot (0.3 meters [m]) was achieved. A sand layer (approximately 6 inches or 15 centimeters [cm]) was then placed atop the geotextile to provide stability and a suitable substrate for benthic organisms. Monitoring during placement confirmed that water quality was not significantly affected; sediment resuspension detected was similar to background values for the Anacostia River; and typical values detected during sand cap placement. After 18 months, PCBs were not detectable in the coke amendment within the geotextile. McDonough et al. (2007) concluded that further studies are required to assess the dominant processes that govern contaminant transport through geotextile layers after placement.

A recent laboratory treatability testing effort conducted by the Space and Naval Warfare Systems Command (SPAWAR) Systems Center Pacific (SSC Pacific) sought to evaluate the performance of an amendment-coated aggregate material to reduce the bioavailability of PCBs, Hg, and methylmercury (MeHg) to benthic organisms (Kirtay 2012). Powdered activated carbon (PAC) coated on the exterior surfaces of aggregate material was used as the reactive material for these tests. Laboratory toxicity testing (28-day polychaete bioassays) indicated that survivability or growth was not statistically different from the control sediments. Additionally, the PCB bioaccumulation testing found increasing reductions in bio uptake with sediment/reactive media contact time. Concentrations of Hg and MeHg in the amended sediments were higher than in the unamended sediments, but not above the referenced background levels. Based on these results, it was determined that a field scale demonstration of this technology would be conducted in the future at the test site.

3.1.1.1 Short-Term Effectiveness

The use of adsorbent technologies does not involve any particular hazards of implementation. Direct injection and shallow mixing techniques are available that minimize the resuspension of contaminated sediment. A recent pilot study on the Grasse River amended the surface sediments with AC using various mechanical means (i.e., tilling and mixing). According to the results, during the application of AC to the surface sediments, water quality impacts were not detected (Alcoa 2007). Amended cap materials may also be placed with minimal resuspension of contaminated sediment. The implementation of Best Management Practices (BMPs) during the installation of amended material (bulk, amended geotextile, or coated aggregate) is necessary to mitigate impacts to the surrounding waters during construction. The adsorptive materials would immediately begin removing dissolved contaminants from porewater that could migrate into the surface water through the sediment or a sediment cap.

Accurate placement is also a necessity; therefore, monitoring the flow within the Site and adjacent waters would be essential. Additionally, the deployment of any amended geotextile mats should incorporate adequate overlap between panels. In the case of an adsorbent amendment, the material should be well-mixed with contaminated sediment or cap materials at application rates determined based on documented contaminant discharge rates and measured adsorption kinetics.

3.1.1.2 Long-Term Effectiveness

Organoclay and AC have both been demonstrated to be very effective and reliable for passively removing organic contaminants from water and thus reducing contaminant mobility in the environment; however, the affected sediments amended with adsorptive materials would not experience a reduction in volume as a result of treatment.

AC is particularly effective for removing trace amounts of organic compounds from water; however, it is susceptible to fouling, if exposed to high concentrations of organic contaminants, such as waters mixed with nonaqueous-phase liquids. Organoclay is very effective for removing nonaqueous-phase liquids from water, and is also effective for dissolved contaminants; although, it may be less effective than AC for removing already very low concentrations of organic contaminants from water (Reible et al. 2008). Other forms of organic carbon, such as agricultural byproducts, have also been added to contaminated sediment or cap material to increase the adsorptive capacity of the sediment or cap and

reduce the concentration of organic contaminants in water. Such amendments may offer a more cost-effective alternative treatment, although the efficacy of such amendments would need to be demonstrated prior to their full-scale use through pre-design testing.
The effectiveness of any adsorptive material relies on its ability to remain in place. Erosion of the adsorbent from any portion of the contaminated sediment area could cause resuspension of contaminated materials into the surface water. The Site is prone to fluctuations in stage and velocity; therefore, necessary means should be taken to provide that the amendment material does not succumb to erosion. The City of Deer Park has proposed to build a detention basin for storm water upstream of the Site. Construction of the detention basin would reduce flow spikes in Patrick Bayou, which may allow continued deposition of sediment in the Site during normal flows while reducing erosional forces during higher flow events, thereby increasing net deposition of sediment on-site. The FS will include an assessment of the need for an armor layer or cap to provide adequate protection against erosion of contaminated sediment and any adsorptive material. Also, any planned adjustments to the profile or inputs to the channel would require further study to demonstrate that flood stage is not adversely affected.

The expected lifetime for proposed cap designs will be evaluated in the FS if appropriate. This assessment would require Site-specific loading rates from groundwater flow and parameters to describe contaminant transport resulting from diffusion. Using analytical methods (i.e., modeling), this information could be compared to the adsorptive capacity of a given amendment material. The time required for the amendment material to reach its adsorptive capacity could provide a conservative estimate of the expected lifetime of an adsorbent cap.

3.1.1.3 Implementability

Adsorbent amendments are available from several vendors, and a variety of placement techniques are also available. Since the adsorbent amendments are applied in-situ, the majority of the work would be completed waterside. Amendments could be added to affected sediment directly from barges. Amended cap materials would be blended prior to loading on barges and then placed mechanically or hydraulically as a slurry. The latter was recently demonstrated as part of a field-scale application at Onondaga Lake in New York.

Granular activated carbon (GAC) was added to a sand slurry and placed via barge atop sediments in water depths ranging from approximately 6 to 24 feet (Parsons 2012). Luthy et al. (2009) describes that mixing or injecting an amendment material can achieve desirable reduction in contaminant concentration. Further evaluation of injection or direct mixing of amendments would be necessary prior to implementing this method for application at the Site.

Amendment-coated aggregate can be placed with a stone-slinger telescopic articulated conveyor mechanism. Stone-slingers can be remote controlled and can spread aggregate or amendment material quickly over large areas; additionally, this equipment can operate landside or waterside depending on the placement application requirements. An excavator mounted on a barge can be used to distribute the material, although this placement method is limited to areas with deeper water that can accommodate the required draft of placement barges. Layers as thin as 6 inches can be achieved by both methods (AquaBlok 2011). Other placement methods are available: crane and clamshell bucket or bulk bag (funneled bag attached to excavator bucket). Layers of amendment-coated aggregate can conform to irregular surfaces. Placing this type of material also reduces the susceptibility of the reactive cap to scour in certain applications without the need for an additional erosion-protection layer (Collins 2011). Additionally, depending on the remedial design criteria, the percent of the reactive material coated on the aggregate can be varied to increase treatment residence time (Collins 2011).

In addition to successful applications at dewatered contaminated sediment sites, amended geotextile mats can be deployed to sequester subaqueous contaminated sediments. Previous application methods have used these mats in conjunction with a sand cap layer. Deployment of a mat with an AC amendment in an aqueous environment may require a sand cap layer to act as a weight to prevent the mat from migrating during and after placement; mats with an organoclay amendment are heavier and can typically be deployed with better consistency (Bullock 2011a).

As discussed above, accurate control of placement is a key component to the success of this treatment method. Advanced global positioning systems can provide real-time location information to operators to document that total coverage of the contaminated areas is achieved.

The landside work would include the coordination of the material delivery, stockpile, and loading areas. Staging areas for all the material and equipment would be essential for this method. Property and facilities need to be identified to stockpile and load capping material either on- or off-Site.

3.1.1.4 Cost

Communication with vendors provided general estimates for the cost of the adsorbent materials. An organoclay-coated aggregate material with 30 percent active material by weight would range from $1,000 to $1,500 per ton (Collins 2011). Similarly, an AC-coated aggregate material with 5 percent active material by weight would cost $400 to $450 per ton (Collins 2011). Raw organoclay and AC material are similarly priced at $1.25 to $1.65 per pound (lb) (Bullock 2011b; Collins 2011). The cost range per square foot (sf) for geotextile mats with AC or organoclay core material is estimated to be $3.00 per sf and $6.00 per sf, respectively (Bullock 2011b, 2012).

Hypothetical remedial action scenarios were developed to provide a common basis for comparing the costs of the different methods identified above. In this assessment, summarized in Table 3-1, the costs are compared on the basis of cost per unit area and normalized based on the assumed quantity of available adsorptive material (i.e., dosage rate). The dosage rates provided in the scenarios are for evaluation purposes only; Site-specific testing would be necessary to ascertain the appropriate quantities of activated material required for remedial action at the Site. The dosage rate used to develop costs for the amendment-coated aggregate options are the baseline values for amendment coating provided by a vendor of that material and assuming the installation of a 6-inch layer of coated aggregate. The dosage rates used for the other three options are based on the amount of amendment material used in the amended geotextile. Therefore, the cost estimate for the amended geotextile option assumes that a single layer of amended geotextile would be used. The cost estimates for the amended cap and amended sediment options were developed assuming the same mass of amendment per unit area as the dosage for the amended geotextile. Installation cost is considered for these scenarios. The assumptions that were made in order to make these comparisons are as follows:

- Amendment-coated Aggregate Application
  - Organoclay and AC materials both have a bulk density range of 85 to 90 pounds per cubic foot (cf) (Collins 2011).
  - Both materials are assumed to be placed with a minimum thickness of 6 inches.
  - Active material coating is assumed to be 30 percent by weight for organoclay and 5 percent by weight for AC.
- Amended Cap Using Raw Materials
  - Amended cap layer for both materials are 12 inches thick, covered by 9 inches of armor stone.
  - Unit costs for both the AC and organoclay range from $1.25 to $1.65 per lb (Bullock 2011b; Collins 2011).
  - Active material is assumed to be 0.8 lbs per sf for organoclay and 0.4 lbs per sf for AC.
- Amended Geotextile Application
  - A 1-foot thick sand cap layer is placed on the reactive core mat.
  - Active material is assumed to be 0.8 lbs per sf for organoclay and 0.4 lbs per sf for AC (CETCO 2012a, 2012b).
- Amended Sediment Layer
  - A 9-inch thick armor layer and a 12-inch thick sand cap layer are placed atop the amended sediment.
  - Active material is assumed to be 0.8 lbs per sf for organoclay and 0.4 lbs per sf for AC (CETCO 2012a, 2012b).

Table 3-1

Cost of Adsorbent Technologies

Adsorbent Technology	Material	Areal Cost[1] ($/acre)	Normalized Areal Cost[2] ($/acre/dose)
Amendment-coated Aggregate Material	AC	$418,000 to $523,000	$197,000 to $247,000
	Organoclay	$1,524,000 to $1,905,000	$113,000 to $142,000
Amended Cap	AC	$190,000 to $247,000	$475,000 to $618,000
	Organoclay	$212,000 to $281,000	$265,000 to $352,000
Amended Geotextile	AC	$295,000 to $369,000	$738,000 to $923,000
	Organoclay	$426,000 to $533,000	$533,000 to $667,000
Amended Sediment	AC	$205,000 to $262,000	$513,000 to $655,000
	Organoclay	$225,000 to $300,000	$282,000 to $375,000

Notes:
1. Areal costs represent the estimated unit cost per area for each adsorbent technology application scenario.
2. These values provide the areal costs from the adjacent column normalized by the amount of active material (i.e., dosage rate) assumed to be in the cap based on the adsorbent technology application scenarios. The amount of active material for each of the scenarios is described in the text that precedes the table.

Complete assessments of the contaminated material location, quantity, and physical properties should be used to establish treatment unit costs that accurately represent conditions at the Site. Additionally, none of the above values includes costs for the stockpiling, offloading, and loading facility. These costs, which would be associated with the combination of remedial technologies in specific remedial alternatives, will be estimated in the detailed evaluation of remedial alternatives in the FS. Further evaluation and design would be necessary to determine the nominal thicknesses of the armor layer for the amended cap and amended sediment layer options, which may differ from the 9 inches assumed for this analysis. Section 4 provides a comparison of this remedial technology to the other treatment technologies described in this document; specifically, Tables 4-1 and 4-2 review the retained treatment technologies and their respective costs.

3.1.1.5 Recommendations

Adsorbents merit further evaluation in the FS as a potentially applicable technology for the remedial action at the Site. Based upon the research and performance data presented for PCBs, Site-specific treatability testing for the FS is not necessary to determine the effectiveness of the adsorptive materials. Should it be selected as a remedial alternative, Site-specific testing would be appropriate to assess specific design parameters of each material (e.g., removal capacity and efficiency).

Other materials that would add organic carbon to the sediment or to a cap material may also be effective and should not be excluded from consideration. Such materials could potentially be identified and tested, should adsorbents be selected as the preferred alternative, during the Site-specific design and testing work.

Screening status: **Potentially Applicable: Sufficient Information**

3.1.2 Solidification/Stabilization

S/S is a category of treatment technologies that has been applied to sediments both in-situ and ex-situ. The application involves blending the affected medium, such as contaminated sediment, with a material that binds it into a solid matrix, increasing the strength, and reducing the permeability, leachability, and mobility of the sediment. Contaminants are contained in the solidified sediment, which for in-situ applications means that the mobility of the contaminants is controlled by both reducing the potential for the sediment to be resuspended and reducing the flow of water through the sediment (permeability), thereby reducing advective transport of contaminants. Stabilization refers to treatment whereby contaminants, typically metals, and more polar nonmetals are also chemically bound to the solidified matrix via chemical or physical reactions (e.g., precipitation, complexation, and adsorption) with the contaminant itself rather than the affected medium (USEPA 2006). Ex-situ applications have been used as both a primary treatment prior to landfilling and as a pre-treatment to eliminate excess free water prior to implementing other process options (e.g., incineration). A variety of binders are available for S/S, although the most common are pozzolanic reagents (e.g., Portland cement, fly ash, cement kiln dust), which are materials that react with lime in the presence of water to form a solidified material.

S/S has been performed in-situ under certain conditions as a primary treatment option or ex-situ following dredging or excavation and may be accomplished using conventional excavators or specialized tillers or augers. In-situ S/S on submerged sediments has had limited use, and has not been demonstrated for full-scale site remediation. For a recent dewatered sediment project, conventional excavators were used to stabilize soft materials in the upland area of a site to provide a stable surface for equipment and worker access during cap installation (Anchor QEA 2012a). Although sufficient water is essential for pozzolanic reactions, excess water can impede curing and require additional reagent making the technology cost-prohibitive. A high percentage of very fine grained sediment can also interfere with S/S. The use of conventional excavators for in-situ S/S would require isolating and dewatering areas of impacted sediment and is likely impractical for use at Patrick Bayou. Isolating areas of the Site for treatment, even temporarily, would reduce the flow capacity of Patrick Bayou and increase the risk of flooding. Proper mix ratios and specialized equipment have been successfully used to solidify subaqueous sediment; however, this variant of the S/S technology has had limited use in the United States. The New Jersey Department of Transportation (Maher et al. 2005) successfully demonstrated the use of a deep soil mixer, a specialized auger, for solidifying subaqueous sediment containing a variety of contaminants without prior dewatering of the sediment. While this technology was used successfully for the demonstration, the equipment used for the project is specialized and may not be available for in-water use. In addition, the deep soil mixer is most applicable for use on deeper sediment, which is not the primary focus for the Site.

Regardless of the application type (in-situ or ex-situ), one of the ultimate considerations for S/S applications is the potential impacts on water quality during and after mixing and curing. Leaching tests can be performed for inorganic and organic chemicals on samples of Site sediments treated with various reagents to assess the performance of different mixtures relative to protecting water quality. The addition of an amendment (e.g., AC) has been shown (Mazzieri et al. 2011) to reduce chlorinated pesticide concentration in leachate. Such amendments should also be evaluated during pre-design testing. Should S/S be performed ex-situ, satisfactory testing results would be necessary prior to landfilling the treated material. The selection of a leaching test should consider the treated state of the material; tests that require particle size reduction (including the Toxicity Characteristic Leaching

Procedure [TCLP]) are inappropriate for materials that are solidified into a rock-like form to reduce permeability and contact between contaminants and water.

3.1.2.1 Short-Term Effectiveness

The implementation timeframe for S/S, both in-situ and ex-situ, is among the shortest of the treatment technologies. For applications of S/S in-situ, after removing standing water (which may be impractical at the Site), sediments may be treated using a conventional excavator bucket to a depth of 10 feet or more, with treatment rates of greater than 400 cubic yards (cy) per day. S/S was used on the first 3 to 5 feet of sediment below grade on a recent project to provide enough strength to the sediments to support equipment placing a cap, and the treatment rates were approximately 900 cy per day (Anchor QEA 2012a). Isolation of significant subaqueous areas of the Site to dewater the sediment may be impractical and would need to be evaluated in the FS. Specialized equipment, such as soil-mixing augers, has been used to treat subaqueous sediment to greater depths if necessary, and potentially, without removing standing water; the actual mixing time for a 10-foot-deep treatment was 10 minutes, and the volume of sediment treated in a single pass was approximately 5 cy (Maher et al. 2005). These times and volumes are provided for information only and Site-specific times and volumes will vary. The mixed sediment and pozzolanic agents cure over time and reach full strength within days or weeks.

The principal hazard of implementing S/S in-situ is associated with mobilizing contaminated sediment during treatment. For treatment using conventional excavators, the treatment area must be isolated from the surrounding surface water and standing water would be removed prior to treatment, which effectively controls potential releases of contaminated sediment (Peckhaus 2011). Specialized equipment for in-situ applications without dewatering, such as soil-mixing augers, has been shown to create minimal disturbance of shallow sediment. Extensive testing of turbidity and total suspended solids was performed during a demonstration of S/S using deep soil mixing augers in Newark Bay (Maher et al. 2005), which is a much larger and deeper body of water than Patrick Bayou. The testing found no impacts in the top one-third of the water column. In the middle one-third of the water column, turbidity and suspended solids impacts were limited to within 125 feet of the deep soil mixing augers, and even in the bottom one-third of the water column, the water quality impacts were limited to within 135 feet of the augers. In a flowing system, potential impacts to water quality would be more transient than in a waterbody with little water movement.

Short-term risks associated with implementing the technology ex-situ are limited and readily monitored, as the majority of the risk is centered on the removal of the contaminated sediments prior to treatment and the re-distribution of impacted sediment downstream. S/S applied ex-situ requires adequate containment and may require storage and treatment for excess water and treated sediment as it cures. Dredged sediments may be dewatered and stabilized waterside in hopper barges using conventional excavators or augers to deliver and mix the stabilizing reagent. Alternatively, S/S may be implemented landside in areas where adequate containment and secondary containment measures have been constructed.

3.1.2.2 Long-Term Effectiveness

S/S is a well-demonstrated technology that has been used for numerous Superfund remedial actions (USEPA 2000). The permeability of treated sediment is reduced and contaminants are encapsulated in the solid matrix, further reducing the mobility and bioavailability of both metals and organic contaminants; however, S/S would not reduce the volume of contaminants. Due to the addition of reagents, the volume of treated material is larger than the volume of contaminated material. S/S has been used for remedial actions for more than 20 years and various forms of concrete have been used in construction for many more years, so the reliability of the treatment is expected to be very high.

The in-situ treatment binds sediment grains into a solid material that resists resuspension by erosive forces. Over many years, chloride ions in brackish water would diffuse into concrete and weaken the solid matrix. Unlike structural concrete, however, the shear strength of solidified sediment is not critical to its performance. Assuming that chloride attack weakens the solidified sediment, the material may crack and break down into pieces that are erodible over many years, but the mobility of the contaminants would still be controlled, such that the release is negligible.

S/S is required for some dredged sediment to meet waste acceptance criteria at disposal sites. Specifically, S/S can be used to eliminate the free liquid in the sediment so that leachate test requirements for disposal at a permitted upland facility can be met.

3.1.2.3 Implementability

The materials required for S/S are readily available. Portland cement is a common construction material. Fly ash and cement kiln dust, which are often less expensive alternatives to Portland cement, are byproducts of electrical power production and cement production and may be available. In addition, other reagents may be applicable based on the results of Site-specific testing prior to implementation. The use of specialized equipment, such as soil-mixing augers, would be necessary for implementing S/S to submerged sediment at the Site. This equipment is not as readily available as conventional excavators, and available vendors who are actively treating subaqueous sediments have not been identified.

Implementing S/S without the use of specialized soil-mixing equipment would require first isolating and dewatering the areas to be treated. Isolating areas of any significant size would be impractical and may present additional hazards to upstream residents and properties from flooding if a storm occurred while obstructions to flow were in place. This technology may be appropriate for consideration in limited areas that are amenable to isolation and dewatering.

Permits are not required for on-site actions under the CERCLA. The technical requirements of regulations for the protection of water quality would be met through the use of appropriate equipment and BMPs. Water-quality monitoring would be performed to detect impacts and adjust practices as needed.

3.1.2.4 Cost

The USEPA published a review of projects where S/S was selected as the treatment for various media as part of Superfund remedial actions (USEPA 2000). The average cost for 29 completed projects included in the USEPA review was reported to be more than $260 per cy and the average cost, excluding two projects with very high costs, was just under $200 per cy (USEPA 2000). Assuming a 1.3 ton per cy conversion factor, this range equals approximately

$155 to $200 per ton. The wording of the text in the report suggests that these figures are the quotient of the total project costs divided by the volume of material treated. The actual costs for S/S may be less than these figures suggest, although the cost of S/S using conventional equipment would be driven by the cost of dewatering, which would vary greatly depending on the size and topography of the area to be treated. Based on a review of the USEPA's database of completed projects, these cost data are based on a combination of projects where S/S was used on several media including soils and sediments. Costs for S/S using specialized equipment are not available.

3.1.2.5 Recommendation

Ex-situ S/S is a potentially applicable technology for the remedial action at the Site. As noted in Section 3.1.2.3, in-situ S/S would have limited applicability at the Site. Deep soil mixing, which would potentially be applicable to the Site, requires the use of specialized equipment that is not available. The alternative approach for in-situ S/S would require first isolating sections of the Site and removing standing water, which would be infeasible or potentially increase the risk of flooding. Sufficient information is available from investigations and full-scale remedial actions at other sites to evaluate remedial alternatives that incorporate ex-situ S/S following dredging. Therefore, Site-specific treatability testing is not necessary for the FS. In-situ S/S was not retained for further consideration as a remedial technology. As discussed, ex-situ applications of S/S following removal can be implemented as a pre-treatment for other technologies; therefore, on this basis, S/S has been retained.

If a remedy using S/S is selected, then Site-specific treatability testing should be performed as part of the remedial design to identify appropriate solidification reagents and admixture ratios and to confirm the permeability and leaching characteristics of the treated sediment.

Screening status: **Potentially Applicable: Sufficient Information**

3.2 Separation and Extraction

3.2.1 Washing

Sediment washing is a media transfer technology involving the addition of a solution to dredged contaminated sediments to transfer the target constituents from the affected medium into the wash solution. Performance of this treatment technology can be enhanced with various additives such as acids, chelating agents, or surfactants (Peng et al. 2009). This technology can be used to treat sediments contaminated with organic constituents and heavy metals; however, specific considerations must be made for the grain size of the contaminated material, as washing is most applicable to the coarse fraction (Peng et al. 2009).

Media with numerous COPCs would present a specific challenge for washing treatment: identification of an appropriate combination of additives to remove all of the target constituents may not be possible. In such cases, several washing sequences with various additives may be necessary to fully treat the affected sediments.

The washing process can include various materials handling stages. Initial separation of large materials and debris is required prior to any treatment; this can be implemented using screening equipment such as a hopper and vibrating grizzly to remove the coarse fraction and debris. Subsequent screening may be necessary to separate out the smaller grain sized materials—research suggests that the typical feed into a sediment washing system is material smaller than 2 inches.

Material washing begins after all separation has been completed. Fine and coarse-grained sediment materials can be further segregated during the wash process using hydrocyclones, chemicals, or additives. The hydrocyclones serve as an aeration mechanism, which creates a froth[2] atop the mixture; this froth typically contains floatable organic matter and hydrophobic particulate material and is removed from the treatment batch (Biogenesis 1997; Dermont et al. 2008). The aerated sediments are then fed into the sediment washer and cavitation unit to destroy the organic contaminants; portions of the organic contaminants can also be solubilized and transferred to the aqueous phase (USACE 2011). The washed material resulting from this phase is fully treated and can be beneficially reused. Water generated from the washing may still be contaminated with metals and other constituents, which are precipitated out of the solution; the sludge generated can be further processed to remove the excess water (e.g., filter press). The dried sludge material can be disposed in a

[2] The froth flotation technique has been identified by Dermont et al. (2008) and the references cited therein as a likely candidate for fine-grain materials, specifically anoxic dredged materials where metals are in their sulfide forms.

permitted landfill, and the water can be treated at a waste facility and reintroduced into the wash cycle.

According to the available research from the Federal Remediation Technologies Roundtable (FRTR; 1995) and the USEPA[3], a similar process was implemented at the King of Prussia Technical Corporation Superfund Site in Winslow Township, New Jersey (King of Prussia). Cleanup goals were set for 11 metals detected in the affected material from the site, and all of the cleanup goals were met within four months of the initiation of treatment (FRTR 1995).

Other applications are cited in Dermont et al. (2008). Specifically, a total of 37 instances of washing treatment were documented. Of these 37 applications, only nine (including the King of Prussia site) were described as full-scale and were conducted within the United States. The King of Prussia site is the only documented instance of the use of the froth flotation technique at full-scale for a site in the United States; however, the scope of Dermont et al. (2008) only included soil washing applications as applied to soils contaminated with heavy metals.

Another full-scale implementation of the washing treatment technology was conducted at the Springfield Township Superfund Site in Davisburg, Michigan, to treat soils contaminated with PCBs and heavy metals. Treatability testing performed by the soil washing contractor achieved residual concentrations that were below the established cleanup criteria (ART Engineering 2012). Approximately 11,500 cy of material was excavated and treated using a mobile soil washing unit on-site, and all of the PCB concentrated filter cake generated from the treatment process was segregated and disposed off-Site.

3.2.1.1 Short-Term Effectiveness

The implementation of the sediment washing technology requires the removal of the contaminated source material prior to treatment. Dredging operations result in the resuspension of contaminated sediments into the water column. BMPs would be implemented to minimize the release of contaminated sediment from the work area.

[3] http://cfpub.epa.gov/asr/

In addition to the upland treatment facility for dredged sediment, facilities would be required for unloading and stockpiling sediment for transportation by truck to the treatment facility. If there is no location to place a treatment facility adjacent to the Site, transportation of the contaminated sediment to an off-Site treatment facility would require property leasing/acquisition; permitting; and planning, and coordination with public safety authorities to minimize hazards associated with traffic and the potential release of contaminated material.

As discussed in Section 3.2.1, part of the waste stream generated by sediment washing is the effluent. A permitted facility would be required to treat the effluent prior to discharge. Secondary containment and BMPs would be required to prevent releases from these operations to the environment.

3.2.1.2 Long-Term Effectiveness

Washing is an ex-situ treatment technology; therefore, removal of the source material from the Site is required prior to treatment. The risks associated with the contaminated sediment would be fully addressed by the removal of the sediment from the aquatic environment.

This treatment process creates two distinct waste streams. The first waste stream is the washed sediment and the second are the byproducts (i.e., wash water, sludge, and filter cake), which are process dependent. As mentioned in Section 3.2.1, washing is capable of removing organic compounds and heavy metals from contaminated media, which produces a clean fill material for beneficial reuse. Water, sludge, and filter cake generated by this process are further treated. Sludge and filter cake material are concentrated with the constituent(s) removed from the washed media and have increased toxicity, requiring disposal at an approved permitted facility. Off-site disposal depends on the constituent(s) and the resulting concentration(s). The potential for mobility of the constituents in the concentrated media can be verified by TCLP analyses; the results of the TCLP analyses would provide further indication of how the concentrated material should be managed (i.e., as a hazardous waste or not). Ultimately, the washing process reduces the overall volume of contaminated material for disposal or subsequent treatment, if necessary.

3.2.1.3 Implementability

A limited number of commercial vendors were identified while researching available sediment washing treatment options. Such issues regarding the availability of a technology should be considered when identifying and selecting a remedy for the Site.

Land would need to be acquired for the construction of an off-site temporary treatment facility, and permits would be required for the construction and operation of these facilities. Several acres would be required to accommodate the washing equipment and ancillary operations, including: stockpiles for untreated and treated material, equipment storage, and off-gas treatment.

Dredged sediment would need to be transported by barge to a suitable offloading facility where the sediment could be transloaded to truck for transportation to an off-Site facility. Implementation of any ex-situ treatment would require establishing an agreement with an adjacent facility for unloading barges and loading the sediment into trucks.

Since this facility would be located off-Site, access and security are also considerations for any treatment effort. Cooperation from local and State agencies would be necessary to make all parties aware of the requirements of the treatment method and that contractors and their sub-contractors, if applicable, can safely and adequately construct and manage the off-Site facility.

3.2.1.4 Cost

The cost of washing depends on the specific method along with costs of amendments and post-treatment processing and disposal of wastewater, sludge, and treated sediment. The USACE (USACE 2011) prepared a report that reviews an emerging sediment washing technology and found that the projected costs for application ranged from approximately $57 to $76 per cy. Assuming a 1.3 ton per cy conversion factor, this range equals approximately $44 to $59 per ton. These projected costs were estimated from a full-scale demonstration of the technology at the New York/New Jersey Harbor; recent estimates were not available from this vendor, as the referenced demonstration is the most representative of this technology's capabilities and performance (USACE 2011).

Discussions with a vendor not evaluated in the USACE (2011) technology review contact revealed a similar cost range of $45 to $60 per ton (Seward 2012); however, the cost to permit a treatment site and establish the necessary infrastructure to accommodate the dredged material has not been included in this range.

Costs for dredging, decontaminating, offloading, rehandling, and transport of the material are not included in these estimates. Also, the cost for the establishment of an intermediary facility used for barge offloading and truck loading has not been included in the above unit costs. Additionally, the costs for land acquisition to construct the treatment area are not included in the unit cost ranges.

3.2.1.5 Recommendation

Sediment washing has been implemented as a full-scale remedy for one former Superfund site where PCBs were present in the affected medium. The available research does not provide evidence for many other full-scale applications in the United States. As discussed in the previous sections, washing can be enhanced by the addition of surfactants and other additives to solubilize weakly bound metals and organics and is most effective for treating sand and gravel-sized sediments; however, different processes within the washing sequence (e.g., froth flotation) may increase efficacy for fine-grained material. Regardless, sediment characterization data should be evaluated by a potential vendor to affirm the applicability of this technology to the material found on-Site.

Prior to selection as a remedy for the Site, additional vendors for this technology may need to be identified. Initial vendor contact indicates that although typical washing applications are conducted for contaminated soils, sediments are also capable of being treated. However, after selecting this technology as a part of the remedy for the Site, Site-specific testing would provide necessary information to evaluate the appropriate components of the treatment application (e.g., processing equipment and the necessary wash additives). Such testing is required prior to implementation and can typically be provided through the vendor (Seward 2012).

Screening status: **Potentially Applicable: Sufficient Information**

3.2.2 Electrokinetics

Electrokinetic remediation applies a low-voltage direct current (DC) to the affected media to desorb and then remove metals and polar organic compounds from contaminated soils and sediments, or treatment may occur in-situ such that all chemicals are degraded without the need for extraction and further treatment (U.S. Army Environmental Center [US-AEC] 2000). This technology is an in-situ process that involves the installation of anodes and cathodes into the affected media along with any ancillary processing equipment necessary to complete the removal or extraction of contaminants. Several driving forces are present in the form of gradients across the affected media during the treatment: charge, pressure, concentration, and temperature (Iyer 2001).

For the purposes of this document the term "electrokinetics" will refer to those technologies that employ either one or the other phenomena associated with the application of electrical current to soils and sediments; electromigration (traditionally used to mobilize heavy metals) and electroosmosis (induce the transport of water and organic compounds)[4]. The remaining components of electrokinetic remediation are: alterations in ambient pH, and electrophoresis. These facets of the treatment are interrelated, as a result of these processes occurring simultaneously (depending on the conditions of the media) during the application of the electrical current. The magnitude and polarity of the charge influences the direction and rate of the transport of ionic species. The electromigration transport mechanism attracts the ions and charged particles to the electrodes (US-AEC 2000). The alteration in pH at the anode (oxidation of porewater hydrogen ions) and cathode (reduction of porewater to form hydroxyl ions) creates acidic and basic conditions, respectively. In turn, these ions are subject to the electromigration mechanism; however, the migration of the acid front toward the cathode is nearly two times faster than the base front to the anode (US-AEC 2000). Electroosmosis (mass flux) is the transport of water from the anode to the cathode, and electrophoresis is the movement resulting from charged colloidal species (Iyer 2001).

[4] The FRTR's discussion of one particular technology that utilizes electroosmotic transport is cited under the headings of "Hydraulic Fracturing" (2007a) and "Other" (2004). Regardless, for the purposes of this document the multiplicity in nomenclature will not be adopted, and for clarity, only electromigration and electroosmosis will be utilized as descriptors for the technologies discussed herein.

Non-ionic species, both inorganic and organic, would also be transported along with the electroosmosis induced water flow.

Electrokinetics treatment systems may be in the form of wells installed in an array of anode-cathode pairs. Each well along with the adequate power supply may include extraction mechanisms to remove the contaminants that have accumulated at these locations and off-gas collection and treatment equipment (US-AEC 2000). This process has been applied as a field-scale application in both the upland area and submerged marine sediments, both applications were targeting the removal of heavy metals (chromium, cadmium, and Hg) (US-AEC 2000; USEPA 2007). Other arrangements have a “layered” approach such that the anode and cathode are separated by a sequence of layers of a treatment medium (e.g., zero-valent iron) that the contaminants and groundwater drawn by the electroosmotic flow would pass through during the treatment process (Athmer 2004).

Targeted contaminants for this treatment method are heavy metals and polar organic compounds (FRTR 2007a). Evaluations of affected media should identify all contaminants present, as the treatment process has been shown to alter the chemical properties during treatment; a previous application of this technology has documented different metals speciation for lab and field testing of materials from the same site (US-AEC 2000). Additionally, hazardous byproducts (trihalomethane and acetone, specifically) and the formation of hazardous gases (chlorine and hydrogen sulfide) have been observed as a result of the treatment process; the latter was identified as a result of the presence of sodium chloride in the soil and groundwater and the presence of metal sulfides in the soil (US-AEC 2000). Therefore, initial testing of this treatment technology for application should include a thorough evaluation of the byproducts to provide optimum performance and adequate treatment of off-gasses.

Several applications of this technology were reviewed while researching for this document; however, only one involved treatment at a Superfund site (Paducah Gaseous Diffusion Plant) using a patented electrokinetics (specifically electroosmosis) remediation method. The target contaminant was the solvent trichloroethene (TCE) present in site soils, and the treatment successfully reduced concentrations from a maximum of 1,500 milligrams per kilogram (mg/kg) to a maximum of 4.5 mg/kg (Athmer 2004).

Other field scale applications of electromigration technologies have not performed as anticipated. Specifically, an application at the Naval Air Weapons Station at Point Mugu, located in Ventura County, California, was unable to successfully remove chromium and cadmium from site soils. During the treatment cycle there were detectable levels of hazardous byproducts in the electrode wells (discussed above: chlorine and hydrogen sulfide gas), and also the electrochemical reactions accelerated the dechlorination of organic contaminants, which resulted in the formation of vinyl chloride in some locations (US-AEC 2000). Another application, which was conducted in 2002 to 2003, as part of the USEPA Superfund Innovative Technology Evaluation (SITE) program, attempted to mobilize and remove Hg from submerged sediments in Bellingham, Washington. Ultimately, this demonstration did not provide evidence of a significant change in Hg concentration at the test site (USEPA 2007). Additionally, sampling for PAHs at the site indicated that there was no significant dechlorination mechanism at work, as concentrations remained at the same or similar levels throughout the demonstration (USEPA 2007).

3.2.2.1 Short-Term Effectiveness

The USEPA (2007) assessment found no adverse impacts to the surrounding area as a result of the demonstration project. In-water work associated with the installation of electrode wells would require the implementation of BMPs to mitigate resuspension and transport of source material off-site. However, as previously discussed, no successful applications of this technology in conditions similar to those found at the Site have been found while conducting research for this document.

3.2.2.2 Long-Term Effectiveness

Electrokinetic remediation is an in-situ technology that intends to remove all of the target contaminants from the affected medium without excavation thereby reducing the toxicity, mobility, volume of both organic and inorganic constituents. Post-treatment of the soils and sediments may require additional enhancement to adequately recover from the treatment; while this occurrence has not been observed at the previous applications, it should be considered when evaluating long-term use and needs for the Site (US-AEC 2000). Additional monitoring may be required post-treatment to evaluate the efficacy of the treatment. Also, if this method is intended to treat the source material, substantial monitoring may be required to verify complete treatment and document that the electrokinetic application has not transported any contaminants into areas adjacent to the treatment zones. No available research indicates that heavy metals or organic constituents can successfully be removed from submerged sediments.

3.2.2.3 Implementability

As documented by the FRTR (2007a), ambient moisture content of the affected medium is an important characteristic to consider prior to selecting this technology, specifically optimum conditions are between 14 to 18 percent with marked decrease in performance for moisture content below 10 percent. Higher moisture content, the condition of in-situ sediment, can significantly interfere with this technology.

As presented in the research of previous applications, there were significant implementability challenges for treating submerged sediments in-situ. The USEPA (2007) reported that such an application found that the performance of the treatment system slowly degenerated over time and was susceptible to corrosion and degradation at the electrodes. The majority of the Site is inundated year-round and would require treatment of submerged sediments. Available research has not indicated that there has been a successful application of this type to date or an available vendor that would be able to provide treatability testing of electromigration technologies.

3.2.2.4 Cost

Available vendors for the treatment of a suite of chemicals as found on-Site have not been identified during the research for this document. Therefore, previous costs from field and full-scale applications will be the basis of the information presented in this section. As can be surmised from the technology type, this process is energy intensive. Average industrial energy costs for the state of Texas are available online from the U.S. Energy Information Administration[5]. The January 2011 and January 2012 average retail costs for electricity in the industrial sector in Texas are 5.88 cents per kilowatt-hour (kWh) and 5.76 cents per kWh, respectively. According to the FRTR (2007a), extraction of heavy metals may be

[5] http://www.eia.gov/electricity/monthly/

expected to require approximately 390 kWh per cy[6], or roughly $23 per cy, which is only a portion of the actual implementation cost[7]. As described by the USEPA (2007), the SITE demonstration conducted in Bellingham, Washington, was estimated to cost $388,500 to treat approximately 167 cy of contaminated sediments (roughly $2,325 per cy). Energy expenditures for this project were orders-of-magnitude less than what the FRTR (2007a) estimates and only represented 1 percent of the overall estimated demonstration cost.

3.2.2.5 Recommendations

Based on the available research, this technology was not found to be effective to mobilize and satisfactorily treat heavy metals (Hg) and PAHs simultaneously during a USEPA field-scale demonstration (USEPA 2007). The technology is also inapplicable to saturated sediment (the contaminated medium at the Site) and PCBs (the principal contaminant of concern). Moreover, available vendors for the application of an electromigration technology were not revealed during the literature review and research conducted for this document. Therefore, this technology is considered inapplicable for treatment of the submerged sediments at the Site.

Screening status: **Inapplicable**

3.3 Thermal Destruction and Immobilization

3.3.1 Incineration

Incineration of environmental media or waste contaminated with organic constituents (e.g., PCBs) requires high temperatures (greater than 1,200°F) and relatively long residence times (30 to 90 minutes) (USEPA 1998). This method volatilizes the contaminants from the environmental matrix. The vapor containing air and organic contaminants reacts to form carbon dioxide and water vapor. Other contaminants are formed if oxidation is incomplete. Permits for incinerators strictly limit the allowable generation of products of incomplete combustion (PIC), and operating conditions (temperatures, residence times, contaminant

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[6] This rate assumes spacing between electrodes is 3.3 to 5 feet.

[7] The FRTR (2007a) provides an estimate of roughly $90 per cy for the full-scale application of this technology; however, additional supporting information (i.e., rationale, site conditions, source information, contaminants) for this estimate is not given. The energy expenditure provided by the FRTR (2007a) represents 26 percent of this cost.

inflow, and excess air flow) are carefully controlled to maximize the destruction of contaminants and minimize the generation of PICs. Based on the type of incinerator, multiple heating chambers may be necessary to achieve the residence time required to fully oxidize the contaminated material. The portion of the material that cannot be incinerated (i.e., fly ash) is removed from the system. As required by emissions permits, the off-gases are captured and treated by a scrubber system prior to release.

Both the ash material produced and the off-gas released from the incinerator system is scrutinized heavily for contaminant content. In order to be permitted, an incinerator facility must meet local, State, and Federal requirements for emissions standards. Prior to selecting a commercial incinerator facility for treatment, sediments from the Site must be characterized to verify that the existing permit requirements would be met.

Other documented methods of rotary kiln thermal treatment have been shown to generate products that can be beneficially reused as aggregate or components of cementitious mixtures. Two such treatment methods are outlined by the USACE in a recent technology evaluation report (USACE 2011). Both methods cited therein have been applied in pilot scale studies; however, the research indicates that neither technology has current commercial availability in the United States. As a result, traditional incineration methods will only be considered for the subsequent evaluations of effectiveness, implementability, and cost.

3.3.1.1 Short-Term Effectiveness

Incineration requires the removal of the contaminated source material prior to treatment. The short-term effectiveness considerations for ex-situ treatment technologies were previously discussed in Section 3.2.1.1.

In addition to the upland treatment facility for dredged sediment, facilities would be required for unloading, dewatering (if required), and stockpiling sediment for transportation by truck to the treatment facility. Transportation of the contaminated sediment to the treatment facility would require planning and coordination with public safety authorities to minimize hazards associated with traffic and the potential release of contaminated material.

Water drained from the sediment would need to be treated at the dewatering location prior to release or collected in tanks for treatment at another facility. Secondary containment and BMPs would be required to prevent releases from these operations to the environment.

3.3.1.2 Long-Term Effectiveness

Incineration is an ex-situ treatment technology; therefore, removal of the source material from the Site is required prior to treatment. The risks associated with the contaminated sediment would be fully addressed by the removal of the sediment from the aquatic environment. As mentioned in Section 3.3.1, incineration is capable of removing PCBs from contaminated media, and chemically altering the PCBs to harmless constituents.

Incinerators operating in compliance with environmental permits have been shown to effectively and safely treat sediment and debris contaminated with PCBs and related compounds. The toxicity, mobility, and volume of organic constituents would be significantly reduced as a result of treating affected sediment from the Site via incineration. Metals present in the sediments would not be treated by incineration; therefore, stabilization of the ash prior to landfilling may be necessary if sediment containing elevated concentrations of metals was incinerated. Waste characterization performed after remedy selection would identify the need for further treatment beyond incineration.

3.3.1.3 Implementability

Implementability concerns for incinerating dredged sediment are similar to those presented in Section 3.2.1.3. However, the primary exception is that two commercial incinerator facilities are located in the vicinity of the Site. As previously discussed, waste characterization would be necessary prior to selecting either facility to verify that the sediment meets all applicable permitting criteria for these facilities.

3.3.1.4 Cost

Treatment costs for incineration were obtained from a facility in the vicinity (75 miles) of the Site. The waste would be transported to the facility in roll-off boxes. The unit cost for incineration is $900 per ton, with a minimum charge of $5,000 per shipment (approximately 6 tons) (Stringer 2011). Treatment costs for water removed from the sediment were also obtained. If the water contains less than 5 percent solids, it can be delivered in a vacuum tanker truck and the treatment cost is approximately $300 to $500 per ton (Stringer 2011). Water containing greater than 5 percent solids along with sludge material can be transported to the facility in a vacuum box, which would have a unit cost of $900 per ton (Stringer 2011).

Additional costs for dredging, decontaminating, offloading, rehandling, and transport of the material are not included in these estimates. Also, the cost for the establishment of an intermediary facility used for barge offloading and truck loading has not been included in the above unit costs.

3.3.1.5 Recommendations

Incineration has been proven to successfully destroy PCBs in contaminated media. Further coordination and cost estimate development for the dredging, decontaminating, offloading, rehandling, and transport would be necessary to fully resolve the applicability of this method to the current Site conditions.

Screening status: **Potentially Applicable: Sufficient Information**

3.3.2 Thermal Desorption

Thermal desorption has been previously implemented as a treatment method for contaminated sediments at Superfund sites with high levels of organic contaminants (e.g., dioxins, PCBs, PAHs). This technology can be applied either as an in-situ or ex-situ remedy. However, since the affected sediments at the Site, which are within the bayou, are fully saturated and typically below the waterline, the in-situ treatment is not applicable in its traditional sense. Rather, sediments can be removed, stockpiled, and treated in piles. Further description of this method is provided below. Additionally, an on-Site thermal desorption processing unit could also be constructed on land adjacent to the Site and utilized for treatment of affected sediments. Such units have been previously used at various Superfund sites.

The in-situ and in pile thermal desorption (ISTD and IPTD, respectively) technology uses a heated negative pressure environment to treat contaminated sediments. A variant of the

IPTD is performed in a barge (Baker et al. 2006), which could be applied to material at dockside locations; although, this method has not been applied to any of the researched demonstration- or field-scale tests presented below. Reduced pressure is used to lower the temperature at which contaminants desorb and volatilize from the affected soil or sediment. Thermal conduction heating is used to raise the temperature of the affected medium for residence times of up to several days—42 days for soil treatment at the Missouri Electric Works, a site with PCB contamination (Stegemeier and Vinegar 2001). Most of the contaminants are destroyed in place by oxidation or pyrolysis; other volatilized contaminants are extracted and treated outside of the piles.

PCBs and other organic constituents are removed from the affected medium by oxidation, pyrolysis, and volatilization. Previous research indicates that thermal desorption via IPTD is capable of removing 95 percent to 99 percent (or more) of the contaminant from the sediment (Baker et al. 2006).

IPTD was evaluated as a treatment for the PCB-contaminated sediment from the Site. Differences between IPTD and the other treatment method variants are noted in the following discussion. As indicated by the IPTD name, excavated material is placed in piles or "cells" for treatment. Each cell is constructed above ground with a foundation, containment berms, insulating walls and cover, and treatment wells. Three types of wells are used for treatment: 1) heater wells, 2) heater-vacuum wells, and 3) air inlet (injection) wells. Each type of well, as described by their names, serves to: deliver heat, remove volatized contaminants, or provide air to facilitate oxidation reactions. The spacing and placement of wells is subject to the design constraints presented by a particular project. Research suggests that the spacing between the wells should not exceed the total depth of contaminated soil/sediment. Wells are typically laid out in a hexagonal pattern, such that the heater-vacuum wells are located at the center of each hexagon. The wells may be oriented horizontally or vertically (Baker 2011a; Baker 2011b).

Thermal desorption processing units differ from the IPTD treatment method in that all of the affected sediment is conveyed through a reactor (desorber) where it is heated, either directly or indirectly, as part of the treatment (FRTR 2007b). Similar to the IPTD method described above, direct heating of the media can cause oxidation of the contaminants, as well as desorption. Off-gasses are treated for any volatized contaminants and to remove any particulate matter, which must also be treated.

Several Superfund sites have utilized the thermal desorption technology as a treatment remedy. At the Sangamo/Twelve-Mile Creek/Hartwell PCB site in Pickens, South Carolina, thermal desorption was used to treat soils and sludge (48,200 cy reported by the USEPA) contaminated with PCBs. The initial PCB concentration in the affected medium was 40,000 mg/kg; the cleanup standard of less than 2 mg/kg was achieved after treatment. The Wide Beach Development Superfund site in Brant, New York combined the thermal desorption technology with dehalogenation by pre-treating the affected soils (23,333 cy reported by the USEPA) with the polyethylene glycol (PEG) reagent. The initial concentration of PCBs was reduced from a maximum of 5,000 mg/kg to a range of 11 to 68 mg/kg after pre-treatment. Subsequent treatment by thermal desorption further reduced the concentrations to concentrations at or below the cleanup standard (2 mg/kg).

3.3.2.1 Short-Term Effectiveness

Short-term impacts associated with dredging contaminated sediment, managing the sediment in stockpiles, and transporting the sediment to a treatment facility are discussed in Section 3.2.1.1 and would be the same for thermal desorption. Additional impacts to the surrounding areas resulting from the treatment operations are not expected (e.g., air quality impacts), as this technology has been applied successfully as a remedy at other sites.

3.3.2.2 Long-Term Effectiveness

This treatment method is an ex-situ technology; therefore, removal of the source material from the Site is required prior to treatment. Previous applications of thermal desorption have proven effective for the treatment of organic constituents including PCBs. In the case of IPTD the treated sediment could be beneficially reused unless there are additional contaminants that are resilient to thermal desorption, such as heavy metals (Baker 2011b). Reduction in toxicity, mobility, and volume of organic constituents would occur as a result of treating affected sediment from the Site via thermal desorption.

3.3.2.3 Implementability

A limited number of commercial vendors were identified while researching available thermal desorption treatment options. Such issues regarding the availability of a technology should be considered when identifying and selecting a remedy for the Site.

Implementability concerns for treating dredged sediment with a thermal desorption technology are similar to those presented in Section 3.2.1.3. Land acquisition and facility permitting, development, and operations and maintenance are all critical implementability components to be considered prior to selecting this technology for treatment.

Based on the available information, the treatment time required for each cell of contaminated sediment for IPTD can range from approximately 40 to 150 days; however, this treatment time is dependent on multiple factors, including the quantity and moisture content of the soil. While the IPTD method can handle a dredged slurry of contaminated sediments, the water content of the sediments would affect the time and energy required to heat the matrix (Baker 2011b). Therefore, it may be desirable to dewater the material prior to the IPTD treatment. The preferred dewatering agents are limestone or lime. Additionally, the rate of dewatering should be viewed as a time constraint and must be considered in light of the excavation production rate, the staging area required for dewatering the material, if necessary, and the amount of treatment cells capable of fitting on the treatment site.

During treatment operations, continuous monitoring and testing would be required to evaluate the performance of the facility. A satisfactory record of compliance to the established permits would be necessary to document that no exceedances (e.g., air quality) were detected.

3.3.2.4 Cost

Treatment costs are estimated based on information provided by available vendors. The estimated cost to treat sediments using the IPTD technology is $250 to $460 per cy (Baker 2011b). If a unit weight of 1.3 tons per cy were assumed for the material, then the unit cost range would be $190 to $360 per ton. These figures are a generalization and do not represent an actual quote for services. The unit cost provided is a "turnkey" cost, which includes: design, equipment, and implementation (including materials testing). Disposal of the treated material would be dependent on the post-treatment testing results; this cost is not included in the IPTD unit cost.

Ex-situ treatment using small batch thermal desorption units (20,000 to 25,000 total tons of treated sediment) has a lower unit cost of approximately $100 to $200 per ton (Troxler 2011); however, mobilization, demobilization, and other components incidental to the proper setup and maintenance have not been considered in this cost range.

Costs for dredging, decontaminating, offloading, rehandling, and transport of the material are not included in these estimates. Also, the cost for the establishment of an intermediary facility used for barge offloading and truck loading has not been included in the above unit costs. Additionally, the costs for land acquisition to construct the treatment area are not included in the unit cost ranges.

3.3.2.5 Recommendations

The thermal desorption treatment technology has been field-tested and can successfully remove and destroy contaminants present in soil and sediment matrices. As with any of the ex-situ treatment technologies, in acquiring a facility off-Site, significant challenges would be: 1) identifying suitable locations for a transloading facility and treatment facility; and 2) acquiring the necessary permits for the transloading facility and treatment facility.
While this technology is viable for treating the sediment from the Site for PCBs, the previous thermal desorption applications documented for Superfund sites have not addressed treatment of metals. However, it is likely that the implementation of this technology would require additional treatment to remove or immobilize all heavy metals detected within the Site sediment.

If a remedial alternative is selected that includes thermal desorption, Site-specific testing would be needed as part of remedial design to determine the effect of sediment moisture content on the treatment time. Specifically, for the IPTD method treatment, time would affect the dimensions of the cells and the overall cost of treatment. Additionally, a preferred dewatering agent would also need to be identified as part of the testing.

Screening status: **Potentially Applicable: Sufficient Information**

3.3.3 Vitrification

Vitrification is a thermal stabilization technology that creates a molten product, which solidifies into a glass material that has superior leach resistant properties. This material encapsulates or immobilizes heavy metals and radionuclides. Organic and some inorganic constituents are destroyed during the process via pyrolysis as a result of the extreme heating conditions (2,900 to 3,600°F). Various configurations for vitrification technologies have been developed and tested. As a result, implementation may be either in-situ or ex-situ; however, regardless of the application, the water content of the affected media should be as low as possible to reduce the amount of energy necessary for treatment (Campbell 2012).

A SITE demonstration conducted by the USEPA in 2001 assessed the ability of a glass furnace production unit to vitrify dewatered PCB-contaminated sediment dredged from the Fox River in Wisconsin (USACE 2011; USEPA 2004). The product generated by this process is a glass aggregate that can be beneficially reused. The demonstration, which was part of the USEPA's SITE program, treated 27,000 pounds of dredged sediments (USEPA 2004). However, since the demonstration, no other documented treatment of dredged sediments has been conducted (USACE 2011). As a result, the glass furnace vitrification technology will not be evaluated as part of this document.

Other forms of vitrification technology can be implemented in-situ or ex-situ. For either case, electrodes are installed into a soil or sediment mass, and once current is applied, the media heats to a molten state. Electrical conduction may not be an innate property of the soil or sediment undergoing treatment; therefore, the addition of material (e.g., graphite and glass frit) may be necessary to begin the treatment process (USEPA 1997). Once the medium becomes molten, it conducts electricity throughout the treatment zone. After the molten mass has cooled, it forms a vitreous glass monolith having strength characteristics that can be ten times those of concrete (Thompson et al. 2001). As a result of densification during the molten phase of treatment, this product can also have 20 to 50 percent less volume than the original material (DoE 1997).

As discussed here, in-situ vitrification can be performed on soils or sediments stockpiled within an appropriate containment area. Ex-situ applications, aside from the demonstration scale test discussed above, can be conducted inside a refractory-lined container similar to a roll-off box (Campbell 2012; Finucane and Campbell 2006). Traditional applications of the in-situ vitrification technology have initiated “top down” melts, which, as the name implies, starts melting the affected media at the surface and proceeds to a target depth. This orientation of the melt is restrictive and may inhibit the propagation of gasses (water vapor) from beneath the molten material, which could cause significant safety hazards[8]. Other non-traditional methods can begin melting media at subsurface locations, which over time, form one larger subsurface melt. This method provides added benefits over the top-down orientation, as the free water is heated within the matrix and vapor is allowed to pass between the molten zones as they propagate to the extent of the treatment area (Thompson et al. 2001). Regardless of the melt orientation, appropriate equipment is necessary to trap (i.e., containment hood) and treat off-gasses.

The first full-scale application of the in-situ vitrification treatment technology at a Superfund site was conducted at the Parsons Chemical/ETM Enterprises Superfund site (Parsons) in Grand Ledge, Michigan from 1993 to 1994 (USEPA 1997)[9]. This site was the location of an agricultural chemical processing and packaging plant from 1945 to 1979; as a result of these operations, pesticides, heavy metals, and dioxins were present in the soil and sediment. A removal action was conducted to excavate contaminated materials from the site (3,000 cy total), and nine treatment cells, each 676 sf in area, were constructed to implement in-situ vitrification. During operations releases of certain contaminants beyond the treatment zone were detected; the contractor retrofitted a refractory liner to the remaining cells, which prevented subsequent releases for the remainder of the treatment effort. Vendor estimates for the amount of soil treated per melt ranges from 300 to 672 cy for durations of 10 to 19.5

[8] During a treatability test at the Oak Ridge National Laboratory the in-situ vitrification melt experienced a “melt expulsion event” as a result of excess water vapor present in the treatment medium (DoE 1997).

[9] Unless otherwise noted, the information presented for the Parsons Superfund site is summarized from the available USEPA (1997) documentation.

days; additionally, the power consumption for the treatment ranged from 559,200 to 1,100,000 kWh per melt. Cleanup requirements and State Applicable or Relevent and Appropriate Requirements (ARARs) were identified for four contaminants at the site: chlordane, 4,4'-DDT, dieldrin, and Hg. All of these requirements were met for the off-gases during treatment and the surface soils tested post-treatment. Confirmation testing of the vitrified material was conducted approximately one year post-treatment to allow sufficient time for cooling; these tests included both glass cores (TCLP analyses) and soils beneath the containment area. All samples for Hg, pesticides, volatile organic compounds (VOCs), and semivolatile organic compounds (SVOCs) were reported as none detected.

Another application of the in-situ vitrification method was conducted for the cleanup at the Wasatch Chemical Superfund site in Salt Lake City, Utah. Operations at this site were conducted from 1994 to 1995 to treat approximately 5,600 tons of sludge, soil, and debris in a concrete evaporating pond located on-site (DoE 1997). Contaminants present in the affected materials included dioxins, pentachlorophenol, pesticides, VOCs, and SVOCs. The complete treatment cycle required a total of 37 contiguous melts at an average depth of 8 feet that were conducted across the area (15,625 sf); the average melt rate reported by the USEPA was 5 to 6 tons per hour. During the treatment, contaminants of concern were not detected in the molten product; additionally, samples taken from the containment berm showed no significant evidence of contaminants migrating beyond the treatment area (DoE 1997). Off-gas sampling also indicated the absence of dioxins throughout treatment (DoE 1997).

3.3.3.1 Short-Term Effectiveness

Short-term impacts associated with dredging contaminated sediment, managing the sediment in stockpiles, and transporting the sediment to a treatment facility are discussed in Section 3.2.1.1 and would be the same for vitrification. Considerations for dredging at the Site include the resuspension and movement of source material and the establishment and maintenance of an unloading, dewatering, and stockpiling facility.

An off-Site upland treatment facility would need to be constructed to implement this technology. Berms with adequate containment measures (e.g., concrete cutoff walls and high thermal capacity refractory liners) would need to be designed and constructed at the facility. Adequate space would be necessary for equipment to construct these berms, place contaminated sediment, and conduct the necessary testing during and after treatment. Adequate space on-Site also would be necessary to deploy the off-gas treatment equipment, which according to the consulted research (DoE 1997), usually consists of a "quencher, scrubber, demister, reheater, high-efficiency particulate air filters, and AC adsorption and/or thermal oxidizer."

3.3.3.2 Long-Term Effectiveness

While this technology is evaluated as an in-situ remedy, removal of the sediments from the Site prior to treatment is necessary. As indicated in previous sections, the risks associated with the contaminated sediment would be fully addressed by the removal of the sediment from the aquatic environment. As mentioned in Section 3.3.3, vitrification is capable of destroying organic compounds and some inorganic constituents in the treated material; those contaminants that are not destroyed would be encapsulated within the vitrified product. This material can be left on-Site in the treatment cells, as it has been demonstrated to display superior resistance to leaching; moreover, the life expectancy for this product has been identified as the "geologic time period" for the material, which is similar to volcanic obsidian (DoE 1997 and USEPA 1997). Neither of the examples cited above indicated that the vitrified masses were exhumed post-implementation; however, the characteristics of the material should not preclude disposal in an approved waste facility should that be required. Reduction in toxicity, mobility, and volume of organic constituents would occur as a result of treating affected sediment from the Site via vitrification.

3.3.3.3 Implementability

Only a single commercial vendor was identified while researching available vitrification treatment options. The availability of the required technology should be considered when identifying and selecting a remedy for the Site. Additionally, while the ex-situ vitrification treatment has been successfully conducted in roll-off containers, this method is limited to small volumes of contaminated sediment because of the length of time required for treatment. Implementability issues regarding space requirements and the quantity of necessary off-gas equipment paired with dredging production and the dewatering rates would likely disqualify this type of vitrification treatment.

Further implementability concerns for treating dredged sediment with a vitrification technology are similar to those presented in Section 3.2.1.3. Land acquisition and facility permitting, development, and operations and maintenance are all critical implementability components to be considered prior to selecting this technology for treatment.

3.3.3.4 Cost

Research and discussions with a vendor of this technology indicated that there are several factors involved when considering the cost for treatment (Campbell 2012 and USEPA 1997):

- Energy costs
  - Energy consumption is directly related to moisture content. For sediment with high moisture content, the energy requirement, and therefore the treatment cost would be very high. Therefore, thorough dewatering of all materials prior to treatment is critical.
- Volume
  - Containment areas should be designed to provide optimal treatment depth; previous applications have cited a limitation of approximately 20 to 23 feet.
- Media Properties
  - Oxide composition of the contaminated materials would affect the properties of the melted product.
  - The addition of conductive materials may be necessary to initiate the treatment process, and the addition of glass forming materials may be necessary to form the desired vitrified product.

An order-of-magnitude cost estimate for treatment was not provided by the vendor, as operations costs are based on the design of off-Site upland containment and the volume of dredged sediment, which are both unknown at this point. Previous estimates range from $270 to $1,500 per cy ($210 to $1,200 per ton, assuming 1.3 tons per cy); the unit cost for treatment is inversely proportional to the volume of material treated (DoE 1997; USEPA 1997). Additionally, since the equipment for this technology is mobile, mobilization and demobilization costs would be distance dependent (Campbell 2012).

Costs for dredging, decontaminating, offloading, rehandling, and transport of the material are not included in these estimates. Also, the cost for the establishment of an intermediary facility used for barge offloading and truck loading has not been included in the above unit costs. Additionally, the costs for land acquisition to construct the treatment area are not included in the unit cost ranges.

3.3.3.5 Recommendations

Vitrification has been implemented as a full-scale Superfund remedy. The available research provides evidence for other full-scale and demonstration-scale applications in the United States. However, treating through the vitrification method would cost considerably more than equally effective and more readily available methods. Due to the lack of multiple active vendors and high treatment cost, the vitrification treatment method is not carried forward for further evaluation as part of the FS.

Screening status: **Inapplicable**

3.4 Chemical Destruction and Immobilization

3.4.1 Dehalogenation

Dehalogenation treatments use chemical and thermal processes to break down chlorinated organic compounds in contaminated soil and sediment. Treatment is achieved either through the removal of chlorine (a halogen) atoms from the molecules or through decomposition or volatilization of the contaminants (FRTR 2007c). All of these technologies are applied to the contaminated media ex-situ and require pre- and post-treatment to complete the process (e.g., dewatering, thermal desorption, debris removal, and/or reagent removal). Several methods have been applied as field-scale treatment operations and are described below.

The modified Alkaline/Potassium Polyethylene Glycolate (APEG/KPEG) method, APEG-PLUS, was developed by Galson Remediation Corp. in the late 1980s. The technology uses a mobile treatment facility paired with a modified reagent, which uses potassium hydroxide and dimethyl sulfoxide to remediate contaminated soils and sediments. As outlined by the International Centre for Science and High Technology, this process takes a contaminated matrix, along with the APEG-PLUS reagents, and forms a slurry, which separates the chlorinated contaminants. The slurry is added to a reactor that heats the mixture and causes the PEG molecule to replace the chlorine atoms in a PCB molecule to form glycol ether. The new chemical products are a non-toxic salt and a less toxic, partially dehalogenated organic compound (Rahuman, et al. 2000). Reagents are separated from the soil by washing and the effluent is treated prior to discharge. Recent applications and vendors of this technology were not found while researching for this document; therefore, none of the PEG technologies will be evaluated any further.

The Solvated Electron Technology™ (SET) is a full-scale, ex-situ chemical dehalogenation treatment process. The process involves mixing the contaminated sediment with a solvated electron solution (alkali metal or alkaline earth metal mixed in liquid anhydrous ammonia) in a treatment vessel. Chlorine is removed from the chlorinated organic molecules, leaving the parent contaminant molecule and metal salts, such as sodium chloride. The vessel is then heated using hot water or steam to remove the ammonia for reuse. SET has been used to treat PCB-contaminated sludge and oil from the New Bedford Harbor Sawyer Street site in Massachusetts (Vijgen 2002b). According to the vendor's website[10], five other sites with PCB contamination have been successfully treated. Only one of these sites, the Pennsylvania Air National Guard Site in Harrisburg, is listed by the USEPA (2010) as a full-scale application of SET for PCBs.

Base-Catalyzed Decomposition (BCD) is another full-scale, ex-situ technology that has been successfully applied in the United States and other countries around the world. The patent holder of this technology in the United States is the USEPA. According to the USEPA (2010), this treatment technology requires pre-treatment via thermal desorption to remove the contaminants from the sediment matrix by volatilization. The volatilized contaminants pass through a condenser and are fed into a liquid tank reactor along with sodium hydroxide and a carrier oil. The mixture is then heated for 3 to 6 hours to temperatures above 326°C. The oil is tested post-treatment and the carbonaceous residues formed from the reaction are removed from the mixture; the carrier oil can then be reused for subsequent treatment

[10] http://www.commodore.com

applications (Vijgen 2002a; Vijgen and McDowall 2009[11]). The soil and sediment treated via thermal desorption can be reused as fill material. Vijgen (2002a) reports that a full-scale application of this technology was conducted United States Navy Public Works Center in Guam, and treated 10,000 tons of PCB-contaminated waste. More recently, the BCD technology was used to treat 40,000 tons of PCB-contaminated soil in Warren County, North Carolina (Vijgen 2002a). The cleanup was completed in 2003 (University of North Carolina 2006).

3.4.1.1 Short-Term Effectiveness

As with all ex-situ technologies, chemical dehalogenation requires the removal of the contaminated source material prior to treatment. Short-term impacts associated with dredging contaminated sediment, managing the sediment in stockpiles, and transporting the sediment to a treatment facility are discussed in Section 3.2.1.1 and would be the same for vitrification. Considerations for dredging at the Site include the resuspension and movement of source material and the establishment and maintenance of an unloading, dewatering, and stockpiling facility.

The equipment necessary for the chemical dehalogenation treatment would need to be deployed at an approved location on- or off-Site. Transportation of the contaminated sediment off-Site would require planning and coordination with public safety authorities to minimize hazards associated with traffic and the potential release of contaminated material.

3.4.1.2 Long-Term Effectiveness

The chemical dehalogenation treatment methods are ex-situ technologies; therefore, removal of the source material from the Site is required prior to treatment. The risks associated with the contaminated sediment would be fully addressed by the removal of the sediment from the aquatic environment. Research indicates that dehalogenation is capable of reducing the concentration of PCBs and other organic constituents in contaminated sediment. Following treatment, the sediment would likely require landfilling for ultimate disposal, which would

[11] Vijgen and McDowall (2009) prepared an update to the existing 2002 fact sheet for BCD. The website source (www.ihpa.info) indicates, however, that this resource has not been peer-reviewed. As necessary, both resources are cited for completeness.

limit the exposure point of ecological receptors to residual concentrations; thus, the material would have a negligible long-term impact to the environment. Reduction in toxicity, mobility, and volume of organic constituents would occur as a result of treating affected sediment from the Site via chemical dehalogenation technologies.

3.4.1.3 Implementability

A limited number of commercial vendors were identified while researching available treatment options. Such issues regarding the availability of a technology should be considered when identifying and selecting a remedy for the Site. According to Vijgen (2002a), the two technology providers responsible for previous applications of BCD to sites in the United States are no longer providing this treatment technology, and subsequent communication with the license distributor, BCD Group, Inc., indicates that no company is currently licensed to perform BCD treatment in the United States (Opperman 2011). Only one full-scale application of the SET method is listed for PCBs, which treated 340 tons of soil (USEPA 2010, Vijgen 2002b).

Implementability concerns for treating dredged sediment with a chemical dehalogenation technology are similar to those presented in Section 3.2.1.3. Land acquisition and facility permitting, development, and operations and maintenance are all critical implementability components to be considered prior to selecting this technology for treatment.

3.4.1.4 Cost

The only cost reported for BCD treatment was for a dioxin-contaminated site in the Czech Republic, based on data from 2004, as reported by Vijgen and McDowall (2009).The reported unit cost range is €1,400 to €1,700 per ton. Assuming a 2004 conversion rate of $1.22[12] per euro, the unit cost range becomes $1,700 to $2,100 per ton. With the establishment of a permanent facility, the anticipated cost information for the treatment is €850 to €1,000 per ton. Again, assuming a 2004 conversion rate of $1.22[12] per euro the unit cost becomes $1,037 to $1,220 per ton. There is no cost information available for BCD treatment of PCB-contaminated soil, although it is anticipated that costs would be similar to the treatment of

[12] http://www.oanda.com/currency/converter/

dioxin-contaminated soil. No cost information is available in the research for the SET application to PCB-contaminated materials.

3.4.1.5 Recommendations

Chemical dehalogenation processes have been proven through field- and/or bench-scale testing to reduce PCB and other organic constituent concentrations to acceptable levels; therefore, no testing for these methods is required for the purposes of the FS. As with any of the ex-situ treatment technologies, if a facility were established off-Site, significant challenges would be: 1) identifying suitable locations for a transloading facility and treatment facility; and 2) acquiring the necessary permits for the transloading facility and treatment facility.

Treating the sediment with chemical dehalogenation would also cost considerably more than equally effective and more readily available methods. Additionally, vendors must be established prior to the selection of this technology as a remedy for the Site. If a remedial alternative is selected that includes chemical dehalogenation, Site-specific treatability testing would be needed as part of the remedial design to determine the reagent quantities necessary to reduce the PCB and other organic constituent concentrations to an acceptable level. Due to the lack of multiple active vendors, lack of multiple full-scale operations, and high treatment cost, the chemical dehalogenation treatment method is not carried forward for further evaluation as part of the FS.

Screening status: **Inapplicable**

3.4.2 Photolysis

Wong and Wong (2006) performed laboratory tests to assess the efficacy of photolysis to remove PCBs from a solution with known congener concentrations. These experiments used ultraviolet (UV) lamps surrounding the solutions to provide maximum exposure. Ultimately, it was found that the toxicity of the solution began to increase immediately following the reaction start time. Decreases in toxicity were detected after longer exposure to UV light; however, residual toxicity still remained in the solution.

Based on the lack of field-scale applications and supporting data, this method is not recommended for further evaluation in the FS.

Screening status: **Inapplicable**

3.5 Biological Treatment

3.5.1 Microbial Dechlorination

Bioremediation methods include those technologies that use microbes to metabolize contaminants present in sediments. These organisms require specific conditions for survival (for example, aerobic organisms require oxygen to survive and metabolize contaminants, whereas anaerobic organisms would be inhibited or poisoned by the presence of air). Under the wrong conditions, microbes could produce unwanted chemical by-products, reduce production, or die off. Bioremediation technologies are mostly in the research and development phase.

The dehalogenation capability of specific bacterial groups has been a long-standing research topic. Bedard (2007) presents a research effort that focuses on a specific group of anaerobic bacteria, *Dehalococcoides*. These bacteria are indigenous to groundwater and freshwater systems and are capable of dechlorinating various compounds, including PCBs. The products of dechlorination include less recalcitrant congeners of the parent chlorinated molecules, which can be metabolized by other microorganisms. PCB-contaminated sediments were collected from the Housatonic River in Lenox, Massachusetts, and used to demonstrate that a *Dehalococcoides* group derived from the Housatonic River simultaneously dechlorinated the PCB congeners in Aroclor® 1260. Bedard indicates further research is needed to identify specific conditions and mechanisms of PCB dehalogenation before *Dehalococcoides* can be applied as a bioremediation tool. Due to the developmental stage of microbial dechlorination for the treatment of PCBs, this treatment method is not carried forward for further evaluation as part of the FS.

Screening status: **Inapplicable**

4 SUMMARY AND CONCLUSIONS

This document presents treatment technologies that are considered potentially applicable to the contaminated material detected at the Site. All ex-situ treatment methods would require mechanical removal of the potentially contaminated materials and transportation of the sediment to an off-Site treatment facility. The treatment itself would be performed at a facility that is either independently owned or established specifically for the remedial action at the Site. For all ex-situ treatment technologies, additional facilities would need to be established at or near the Site prior to execution of the treatment (e.g., berthing; loading and unloading; and material stockpiling and dewatering). The addition of such facilities would need to occur prior to implementation of the remedy, thus a method that would use these facilities would require property lease/acquisition and sufficient construction lead-time factored into the implementation schedule. Additionally, ex-situ treatment would require the establishment of appropriate facilities off-Site, except in the case of incineration, for which nearby commercial facilities that can treat material from the Site are available. The establishment of a treatment facility off-Site would require: acquiring land, obtaining permits, and building treatment and support facilities.

Table 4-1 presents a summary of the evaluation of potential treatment technologies. The following technologies are potentially applicable to the Site:

- Adsorbent Technologies
- S/S
- Sediment Washing
- Incineration
- Thermal Desorption

Adsorbent technologies, both organoclay and AC, can effectively reduce the mobility of contaminants in sediments and water. No testing for the FS would be required. Should adsorbent technologies be selected as a treatment for the Site, Site-specific testing would be necessary as part of the remedial design to gather performance data (e.g., removal capacity and efficiency) for each amendment.

Treatability testing for the FS is also not required for S/S, as the effectiveness of this technology has been demonstrated in successful full-scale treatment efforts for similar constituents. If S/S is selected as a treatment for the remedial action, Site-specific testing would be required during remedial design to determine the appropriate solidification reagents and admixture ratios and to confirm the permeability and leaching characteristics of the treated sediment under different conditions. Dewatering would be necessary as part of the removal and transport operations necessary for the implementation of off-Site ex-situ technologies. Dewatering by amendment and S/S differ mainly in the amount of reagent that is added to saturated media; therefore, this technology would likely be included to some degree as part of the ex-situ treatment technologies retained for consideration in the FS. S/S as a primary treatment would require landfilling at a permitted facility for final disposal; landfilling is discussed in Section 4 of the *Remedial Alternatives Technology Screening* (Anchor QEA 2013).

According to the available documentation, sediment washing treatment has been implemented as the full-scale remedy for at least one Superfund site, and this technology has been shown to effectively separate contaminants from affected media and transfer them to different waste streams for final disposal (e.g., landfilling). Treatability testing during the FS is not required for sediment washing. Research and communication with a soil-washing vendor indicates that this technology is applicable to the materials found on-Site; however, testing would be required during the remedial design to identify the actual components and additives necessary for treatment of the materials.

Incineration is a full-scale technology that does not require testing for the purposes of the FS. This technology has been implemented for contaminated soils and sediments at numerous Superfund sites and is capable of destroying the organic contaminants. Heavy metals not destroyed during incineration would remain in the ash byproduct, which may require additional treatment (e.g., stabilization) prior to landfilling. Commercial incinerators are available in Texas and the associated facilities can likely provide support for waste characterization and final disposal of treated sediment. Testing would be required during the remedial design to identify the level of destruction achieved in the ash byproduct.

Thermal desorption is a full-scale technology that does not require treatability testing for the purposes of the FS; however, should either a batch thermal desorption unit or IPTD be selected as a treatment option in the FS, testing the removal rate and efficacy of thermal desorption on small batches of contaminated material from the Site would be necessary as part of remedial design. Previous communications have indicated that the vendors offering this treatment could potentially perform the necessary testing. Tests of this treatment technology should be performed on sediment that has been dewatered using a variety of potential dewatering agents, as dewatering methods would affect the performance of thermal desorption.

Unit costs for each of the retained treatment methods are provided in Table 4-2. The cost for technologies requiring the sediments to be treated ex-situ includes a general assessment of typical costs associated with removing the sediments by mechanical dredging, dewatering using Portland cement, and transporting the material to an off-Site location. Since this assessment includes dewatering with Portland cement as part of the removal costs, a separate line item for S/S treatment is not included. The cost information provided below is meant to aid in the overall assessment of the potential costs expected during certain phases of the removal and treatment processes; a complete cost analysis of each specific remedial alternative will be provided in the FS. These figures are not intended to represent actual cost estimates, as the dredging, transloading, and hauling operations have anticipated an ideal facility that only requires minimal renovations and whose location is near the Site. Moreover, the cost of renovating said facility is not included in the unit costs provided in Table 4-2. Additional assumptions include that the sediment unit weight was assumed to be 1.3 tons per cy, a treatment facility location was also assumed to be located within 50 miles of the transloading facility, and the haul rate was assumed to be $0.55 per ton-mile. Cost estimates for adsorbent amendment are presented on an area basis as described in Section 3.1.1.

Table 4-2

Cost Ranges for Applicable Treatment Technologies

Treatment Method	Application	Treatment Unit Cost Range ($/ton)		Areal Unit Cost Range[1] ($/acre)	
Adsorbent Amendments	In-situ	--		$190,000	$1,905,000
Sediment Washing	Ex-situ	$44	$59	--	--
Incineration[2]	Ex-situ	$900	$1,080	--	--
Thermal Desorption	Ex-situ	$100	$360	--	--

Notes:
1. Areal unit costs are rounded up to the nearest $5,000.
2. An additional 20 percent is added to the unit cost for Incineration to develop an approximate upper end to the cost range.

The final remedy for the Site could involve one or more of the treatment technologies summarized above combined with a variety of more conventional remediation technologies. Ultimately, those decisions will be based on the development of the remedial action objectives and goals for the Site and the outcome of the FS.

5 REFERENCES

Alcoa, 2007. Grasse River Activated Carbon Pilot Study; Construction Documentation Report. November 2007.

Alther, G., 2004. Some Practical Observations on the Use of Bentonite. Technical Note. *Environmental and Engineering Geoscience*. Vol. X. No. 4. November 2004. pp. 347-359.

Anchor QEA, 2011. *Final Baseline Ecological Risk Assessment Work Plan*. Patrick Bayou Superfund Site. Prepared for Patrick Bayou Joint Defense Group. May 2011.

Anchor QEA, 2012a. *Final Removal Action Completion Report, San Jacinto River Waste Pits Superfund Site*. Prepared for U.S. Environmental Protection Agency, Region 6 on behalf of McGinnes Industrial Maintenance Corporation and International Paper Company. March 2012.

Anchor QEA, 2012b. *Draft Baseline Ecological Risk Assessment Report.* Patrick Bayou Superfund Site. Prepared for U.S. Environmental Protection Agency and Patrick Bayou Joint Defense Group. August 2012.

Anchor QEA, 2013. *Draft Remedial Alternatives Technology Screening*. Patrick Bayou Superfund Site. Prepared for U.S. Environmental Protection Agency and Patrick Bayou Joint Defense Group. February 2013.

ART Engineering (website). Soil Washing of PCB, Lead and Arsenic Contaminated Soils at Springfield Township Superfund Site. Cited: May 14, 2012. Available from: http://www.art-engineering.com/Projects/Springfield/Photos.htm

AquaBlok, 2011. Technology Overview – Sub Aqueous Treatment & Sequestration of Contaminants. Presentation. April 2011.

Athmer, C., 2004. In-Situ Remediation of TCE in Clayey Soils. *Soil & Sediment Contamination*, 13(5), 381-390.

Baker, R.S., J.C. LaChance, and G. Heron, 2006. In-Pile Thermal Desorption of PAHs, PCBs and Dioxins/Furans in Soil and Sediment. Proceedings of the International Symposium and Exhibition on the Redevelopment of Manufactured Gas Plant Sites

(MGP2006), Reading, England, April 4-6, 2006. Journal of Land Contamination and Reclamation, 14(2):620-624.

Baker, R.S., 2011a. In-Pile Thermal Desorption of Dioxin Contaminated Soil and Sediment. TerraTherm, Inc., Fitchburg, Massachusetts.

Baker, R.S., 2011b. Personal communication with B. Roth. Ocean Springs, MS. April 22, 2011.

Bedard, D.L., Ritalahti, K.M., Loffler, E.F., 2007. The Dehalococcoides Population in Sediment-Free Mixed Cultures Metabolocally Dechlorinates the commercial Polychlorinated Biphenyl Mixture Aroclor 1260. *Appl. Environ. Microbiol.* April 2007 vol. 73 no. 8 2513-2521.

Biogenesis, (website) Biogenesis™ Sediment Washing Process. Cited: March 23, 2011. Updated: 1997. Available from: http://www.biogenesis.com/ssebbs.html

Bullock, A., 2011a. Personal communication with B. Roth. Ocean Springs, MS. June 30, 2011.

Bullock, A., 2011b. Personal communication with B. Roth. Ocean Springs, MS. July 15, 2011.

Bullock, A., 2012. Personal communication with B. Roth. Ocean Springs, MS. February 22, 2012.

Campbell, B., 2012. Personal communication with B. Roth. Ocean Springs, MS. April 13, 2012.

CETCO, 2012a. Technical Data Reactive Core Mat™ with Granular Activated Carbon Core (GAC). Revised: February 2012.

CETCO, 2012b. Technical Data Reactive Core Mat™ with Organoclay®. Revised: February 2012.

Collins, J., 2011. Personal communication with B. Roth. Ocean Springs, MS. May 6, 2011.

Department of Energy (DoE), 1997. In Situ Vitrification, U.S. Department of Energy, Hanford Site, Richland, Washington; Oak Ridge National Laboratory WAG 7, Oak Ridge, Tennessee; and Various Commercial Sites. Case Study Abstract. 2007 pp 226-247.

Dermont, G., M. Bergeron, G. Mercier, M. Richer-Laflèche, 2008. Soil washing for metal removal: A review of physical/chemical technologies and field applications. *Journal of Hazardous Materials* 152 1-31.

Federal Remediation Technologies Roundtable (FRTR), 1995. *Abstracts of Remediation Case Studies*. EPA-542-R-95-001. March 1995.

Finucane, K.G., B.E. Campbell, 2006. The Treatment of Mixed Waste with GeoMelt In-Container Vitrification. Waste Management 2006 Conference. Tucson, AZ. February 26 to March 2, 2006.

FRTR, (website) 4.5 Electrokinetic Separation (3.2 In Situ Physical/Chemical Treatment). Cited: March 21, 2011. Updated: 2007a. Available from: http://www.frtr.gov/matrix2/section4/4-26.html

FRTR, (website) 4.25 Thermal Desorption (3.6 Ex Situ Thermal Treatment (assuming excavation)). Cited: March 21, 2011. Updated: 2007b. Available from: http://www.frtr.gov/matrix2/section4/4-26.html

FRTR, (website) 4.17 Dehalogenation (Ex Situ Soil Remediation Technology). Cited: March 22, 2011. Updated: 2007c. Available from: http://www.frtr.gov/matrix2/section4/4-17.html#site

Iyer, R., 2001. Electrokinetic Remediation. *Particulate Science & Technology*, 19(3), 219-228.

Kirtay, V., 2012. Demonstration of In Situ Treatment with Reactive Amendments for Contaminated Sediments in Active DoD Harbors. Presentation. Sediment Management Seminar. Ft. Lauderdale, Florida. 2012.

Luthy, R.G., U. Ghosh, T.S. Bridges, and A.J. Kennedy, 2009. *Field Testing of Activated Carbon Mixing and In Situ Stabilization of PCBs in Sediment*. Environmental Security Technology Certification Program. May 2009.

Maher, A., H. Najim, and M. Boile, 2005. *Solidification/Stabilization of Soft River Sediments Using Deep Soil Mixing*. Prepared for the New Jersey Department of Transportation. October 2005.

Mazzieri, F., A. del Frate, and G. Monti, (2011). Stabilisation/solidification of soils contaminated by chlorinated pesticides. *Chemistry & Ecology*, 2733-42.

McDonough, K.M., P. Murphy, J. Olsta, Y. Zhu, D. Reible and G.V. Lowry, 2007. Development and Placement of a Sorbent-Amended Thin Layer Sediment Cap in the Anacostia River. *Soil & Sediment Contamination*, 16(3), 313-322.

Opperman, T., 2011. Personal communication with B. Roth. Ocean Springs, MS. May 23, 2011.

Parsons, 2012. *Capping Field Demonstration Summary Report*. Prepared for Honeywell. February 2012.

Peckhaus, K., 2011. Personal communication with R. Schwarz. Portland, OR. April 25, 2011.

Peng, J.F., Y. Song, P. Yuan, X. Cui, G. Qui, 2009. The remediation of heavy metals contaminated sediment. Journal of Hazardous Materials. 161 (2009) 633-640.

Rahuman, M., Pistone, L., Trifiro, L., Miertus, S. Destruction Technologies for Polychlorinated Biphenyls (PCBs). International Centre for Science and High Technology United Nations Industrial Development Organization (UCS-UNIDO). November 2000.

Reible, D., D. Hayes, C. Lue-Hing, J. Patterson, N. Bhowmik, M. Johnson, J. Teal, 2003. Comparison of the Long-Term Risks of Removal and In Situ Management of Contaminated Sediments in the Fox River. *Soil & Sediment Contamination*, 12(3), 325.

Reible, D., X. Lu, J. Galjour, and Y. Qi, 2008. The use of organoclay in managing dissolved contaminants relevant to contaminated sediments. CETCO Technical Reference 840. TR 840. June 2008.

Seward, C., 2012. Personal communication with B. Roth. Ocean Springs, MS. April 13, 2012.

Stegemeier, G.L., and H.J. Vinegar, 2001. Thermal Conduction Heating for In-Situ Thermal Desorption of Soils. In Hazardous and Radioactive Waste Treatment Technologies Handbook, Edited by Chang H. Oh., Boca Raton, FL, CRC Press, Ch. 4.6-1.

Stringer, W., 2011. Personal communication with B. Roth. Ocean Springs, MS. April 20, 2011.

Thompson, L., G. Huddleston, D. Reichhardt, J. Jones, M. Springer, B. Campbell, 2001. Results from The Non-Traditional (Sub-Surface) In Situ Vitrification Demonstration for Mixed Waste Applications at the Los Alamos National Laboratory. Waste Management 2001 Conference. Tucson, AZ. February 25 to March 1, 2001.

Troxler, W., 2011. Personal communication with B. Roth. Ocean Springs, MS. April 29, 2011.

University of North Carolina at Chapel Hill (UNC), 2006. Afton, NC (Warren County). Exchange Project at the University of North Carolina at Chapel Hill.

U.S. Army Corps of Engineers (USACE), 2011. Mass Balance, Beneficial Use Products, and Cost Comparisons of Four Sediment Treatment Technologies Near Commercialization. Environmental Research and Development Center – Dredging Operations and Environmental Research. March 2011.

U.S. Army Environmental Center (US-AEC), 2000. *In Situ Electrokinetic Remediation of Metal Contaminated Soils Technology Status Report*. SFIM-AEC-ET-CR-99022. July 2000.

U.S. Environmental Protection Agency (USEPA), 1988. *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA*. EPA/540/G-89/004.

USEPA, 1989. *Superfund Ground Water Issue, Facilitated Transport*. U.S. Environmental Protection Agency, Office of Research and Development, Office of Emergency and Remedial Response, EPA/540/4-89/003. August 1989.

USEPA, 1997. CLU-IN (website). Cost and Performance Report: In Situ Vitrification at the Parsons Chemical/ETM Enterprises Superfund Site Grand Ledge, Michigan (USEPA). Published: July 1997. Cited: April 20, 2012. Available from: http://clu-in.org/PRODUCTS/COSTPERF/VITRIFIC/Parsons2.htm

USEPA, 1998. *On-Site Incineration: Overview of Superfund Operating Experience*. EPA-542-R-97-012. March 1998.

USEPA, 2000. *Solidification/Stabilization Use at Superfund Sites*. EPA-542R-00-010. September 2000.

USEPA, 2004. *Minergy Corporation Glass Furnace Technology Evaluation*, Innovative Technology Evaluation Report. National Risk Management Research Laboratory, Office of Research and Development. EPA/540/R-03/500. March 2004.

USEPA, 2006. *In Situ Treatment Technologies for Contaminated Soil*, Engineering Forum Issue Paper. EPA 542/F-06/013. November 2006.

USEPA, 2007. *Electrochemical Remediation Technologies (ECRTs) – In Situ Remediation of Contaminated Marine Sediments*. Innovative Technology Evaluation Report. National Risk Management Research Laboratory, Office of Research and Development. EPA/540/R-04/507. June 2007.

USEPA, 2009. *EPA Region 6 Clean and Green Policy*. September 1, 2009.

USEPA, 2010. Reference Guide to Non-combustion Technologies for Remediation of Persistent Organic Pollutants in Soil, 2nd Edition. 542-R-09-007. September 2010.

U.S. Environmental Protection Agency (USEPA) and U.S. Army Corps of Engineers (USACE), 2000. *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study*. EPA 540-R-00-002. July 2000.

Vijgen, J., 2002a. NATO/CCMS Pilot Study, Evaluation of Demonstrated and Emerging Remedial Action Technologies for the Treatment of Contaminated Land and Groundwater (Phase III), prepared by International HCH & Pesticides Association (Fact Sheet 1, Base Catalyzed Decomposition (BCD)). December 2002.

Vijgen, J., 2002b. NATO/CCMS Pilot Study, Evaluation of Demonstrated and Emerging Remedial Action Technologies for the Treatment of Contaminated Land and Groundwater (Phase III), prepared by International HCH & Pesticides Association (Fact Sheet 9, Solvated Electron Technology (SET™)). December 2002.

Vijgen, J. and R. McDowall, 2009. POPs Technology Specification and Data Sheets for the Secretariat of the Basel Convention, prepared by International HCH & Pesticides Association and Secretariat of the Basel Convention (Base Catalyzed Decomposition (BCD) Fact Sheet and Annex). In Review. June 2009.

Wong, K.H., and P.K. Wong, 2006. Degradation of Polychlorinated Biphenyls by UV-Catalyzed Photolysis. *Human & Ecological Risk Assessment*, 12(2), 259-269.

TABLES

Table 4-1
Treatment Technology Screening Matrix

Technology		Screening Criteria: Effectiveness[1,2]	Screening Criteria: Implementability[3]	Screening Criteria: Feasible Alternative	Screening Criteria: Unit Cost[4]	Screening Criteria: Regulatory Requirements[5]	Vendor Availability[6]	Alternative Retained for Detailed Evaluation[7]
Containment and Immobilization	Adsorbent Technologies	Yes - These amendments are effective in adsorbing organic compounds and immobilizing heavy metals; further testing for amendment type, concentration, and placement method is necessary post-remedy selection	Yes - Equipment and personnel available for product application	Yes	$190,000 -$1,910,000/acre	None	Multiple Vendors	Yes
Containment and Immobilization	Solidification/Stabilization	Yes - Solidification/Stabilization is a proven method to immobilize organic and inorganic contaminants; necessary reagents would require further testing	Yes - Equipment and personnel available for method application; specialty equipment may be necessary for deep-water application	Yes	$155 - 200/ton	None	Multiple Vendors	Yes
Separation and Extraction	Washing	Yes - Washing has been implemented as a remedy for sediments contaminated with organic and inorganic compounds; further testing of wash chemicals and processes is necessary post-remedy selection	Yes - Equipment is available for application; Facility needs to be established for treatment	Yes	$44 - $59/ton	Loading/unloading facility permits are necessary; Treatment site permits are necessary prior to implementation	Limited Vendors	Yes
Separation and Extraction	Electrokinetics	No - Electrokinetics has successfully remediated soils contaminated with chlorinated solvents; however, successful applications to both metals and organics was not found during the literature review	No - Vendors of the electromigration technology for heavy metal remediation were not available.	No	N/A	N/A	No Vendors	No
Thermal Destruction and Immobilization	Incineration	Yes - Incineration is a proven full-scale technology for destruction the destruction of PCBs, dioxins, and organic contaminants; byproducts containing heavy metals would require stabilization and landfilling	Yes - Off-site facilities are available for treatment of sediment, sludge, and water	Yes	$900 - $1,080/ton	Loading/unloading facility permits are necessary; Incineration permits retained by commercial facilities	Multiple Vendors	Yes
Thermal Destruction and Immobilization	Thermal Desorption	Yes - Thermal Desorption is a proven full-scale technology for PCB, dioxin, and other chlorinated organics; remediation of heavy metals is uncertain	Yes - Equipment is available for application; Facility needs to be established for treatment	Yes	$100 - $360/ton	Loading/unloading facility permits are necessary; Treatment site permits are necessary prior to implementation	Limited Vendors	Yes
Thermal Destruction and Immobilization	Vitrification	Yes - Vitrification destroys organics and some inorganics via pyrolysis; heavy metals and other contaminants (radionuclides) are encapsulated inside the vitrified mass	Uncertain - Equipment is available for application; Facility would need to be established for treatment	Yes	$210 - $1,200/ton	Loading/unloading facility permits are necessary; Treatment site permits are necessary prior to implementation	Limited Vendors	No

Table 4-1
Treatment Technology Screening Matrix

Technology		Screening Criteria: Effectiveness[1,2]	Screening Criteria: Implementability[3]	Screening Criteria: Feasible Alternative	Screening Criteria: Unit Cost[4]	Screening Criteria: Regulatory Requirements[5]	Vendor Availability[6]	Alternative Retained for Detailed Evaluation[7]
Chemical Destruction and Immobilization	Polyethylene Glycolate	Uncertain - Polyethylene Glycolate reagents (Alkaline and Potassium) have been successfully applied to PCBs	No - Vendors and recent applications were not available	No	N/A	N/A	No	No
Chemical Destruction and Immobilization	Solvated Electron Technology	Yes - Solvated Electron Technology has been successfully applied to PCBs, dioxins, and other chlorinated organics; complete remediation of heavy metals is unlikely--additional treatment is necessary	Yes - Vendor is available and has tested the technology at pilot-scale; application to PCBs, dioxins, and chlorinated organics is certain	Yes	Not available from the consulted vendor	Loading/unloading facility permits are necessary; Treatment site permits are necessary prior to implementation	Single Vendor Only	No
Chemical Destruction and Immobilization	Base-Catalyzed Decomposition	Yes - Base-Catalyzed Decomposition is a proven technology for the treatment of chlorinated organics--additional treatment would be required for heavy metals; no full-scale applications are currently being conducted in the U.S.	No - Vendors listed in documentation are no longer available and no company is currently permitted to apply this technology in the U.S.; application to dioxins is certain	Yes	$1,037 - $1,220/ton	Loading/unloading facility permits are necessary; Treatment site permits are necessary prior to implementation	No	No
Chemical Destruction and Immobilization	Photolysis (UV Degradation)	Uncertain - Complete degradation of PCBs by photolysis has not been documented; heavy metals are not treated	No - Equipment and personnel available for material distribution; area required for treatment would be excessive	No	N/A	N/A	No	No
Biological Treatment	*Dehalococcides*	Uncertain - *Dehalococcides* is developmental fo dehalogenating PCBs; bench-scale treatment has not been conducted	No - Equipment for treatment and testing has not been developed	No	N/A	N/A	No	No

Notes:
1. Those methods described as ex situ applications completely remove the contaminated source material by dredging; efficacy for these methods is considered to be complete.
2. PCB - polychlorinated biphenyl
3. Dredging operations must also consider the implementability in terms of coordinating with navigation channel traffic as needed for mobilization/demobilization, dredging activities, and material transport.
4. Treatment costs do not include the excavation of contaminated sediments, the establishment of the off-site unloading/loading facility, or transportation of the contaminated material. Additionally, these costs do not include the testing, design, and development of the treatment method.
5. Ex situ treatment will also require a permitted facility that is available to receive waste barged from the Site and that can accommodate equipment necessary to unload barges and load trucks or rail cars for delivery to the treatment site.
6. The license distributor, BCD Group, Inc. was contacted; however, they are not a vendor of the Base-Catalyzed Decomposition treatment technology.
7. Further site-specific testing is suggested in the design phase of the project if this technology is carried forward from the Feasibility Study.

FIGURES

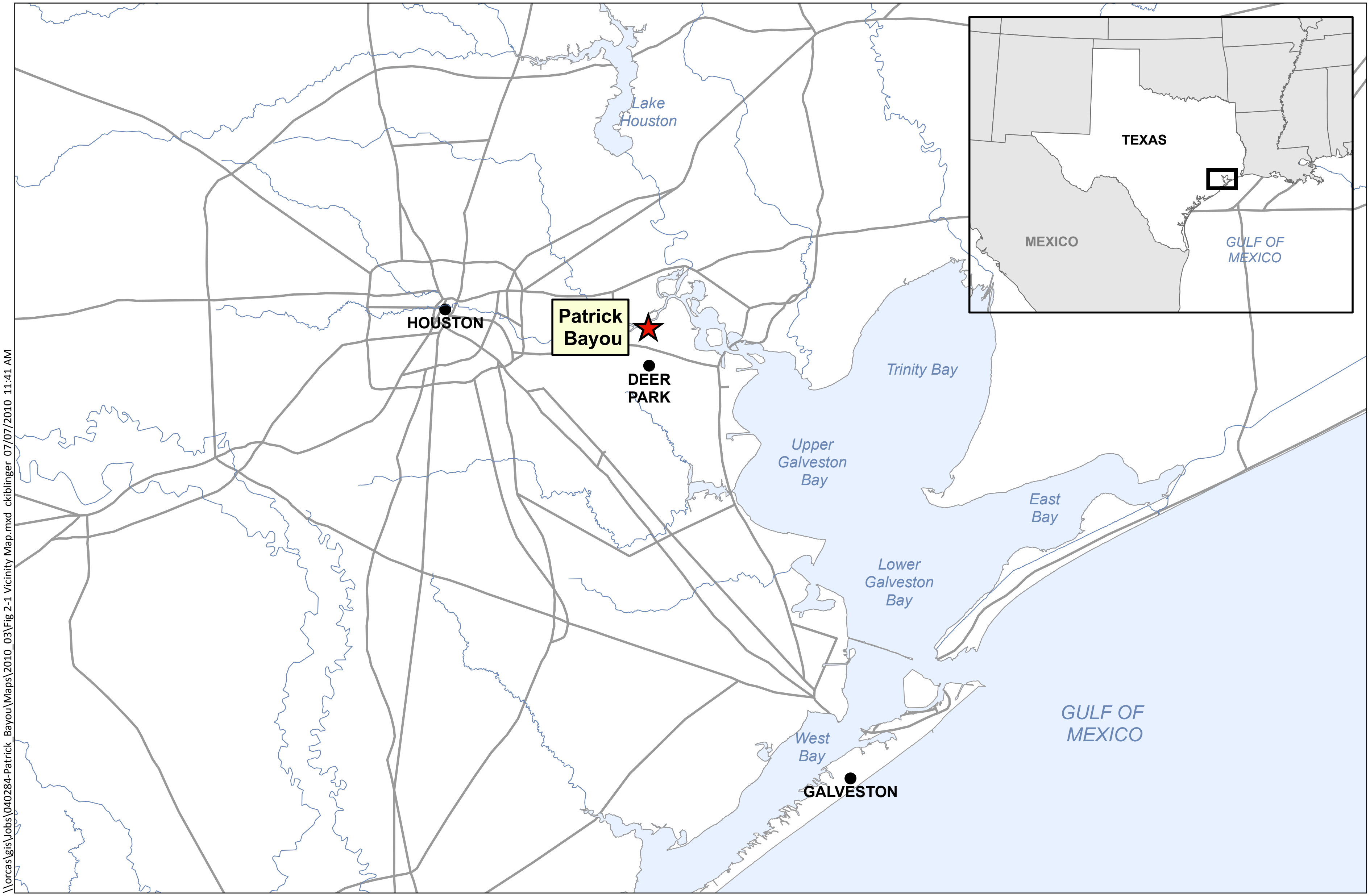

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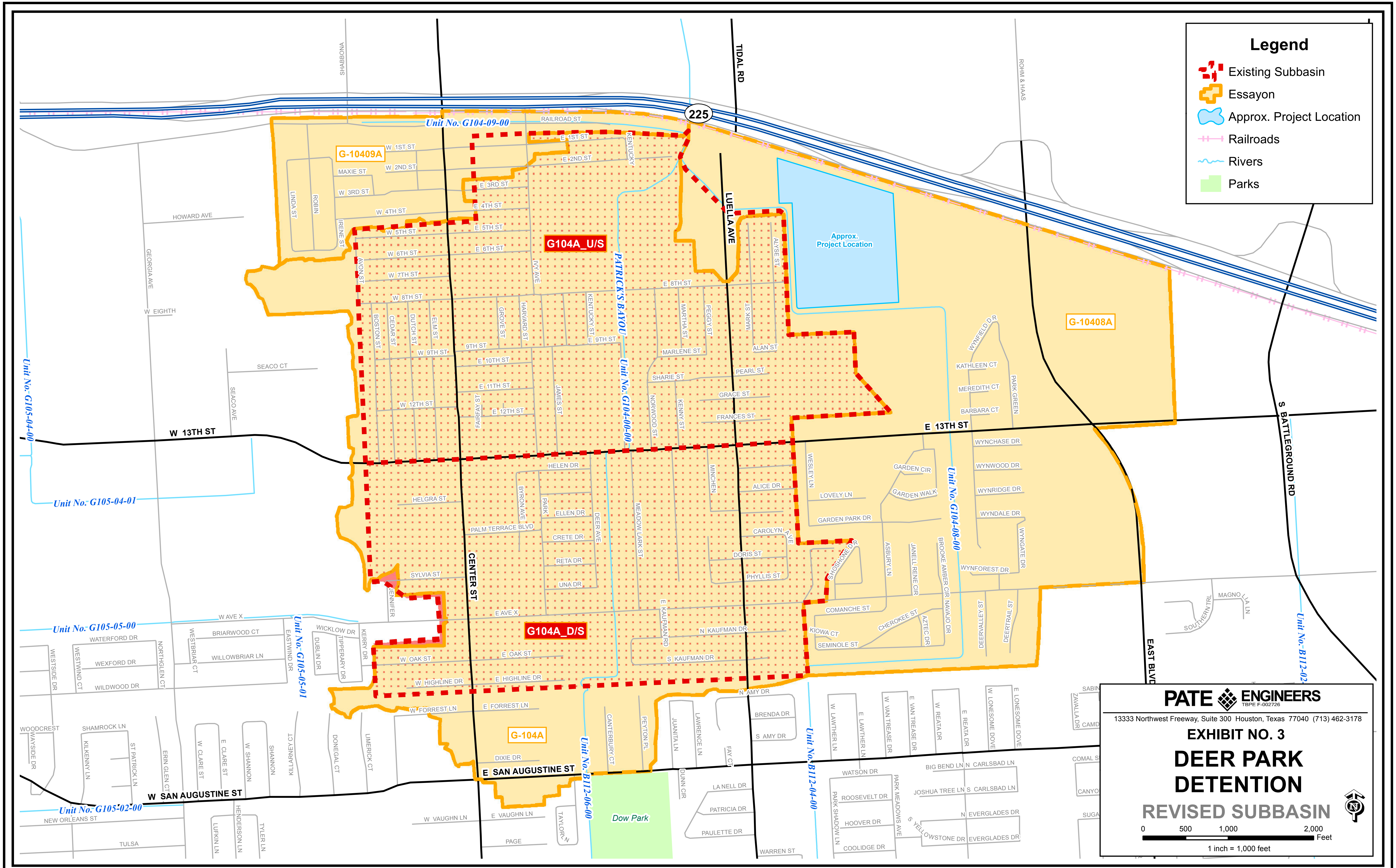
Figure M-1
Vicinity Map
Treatment Technology Review
Patrick Bayou Superfund Site

APPENDIX B
PROPOSED DETENTION BASIN PLANS



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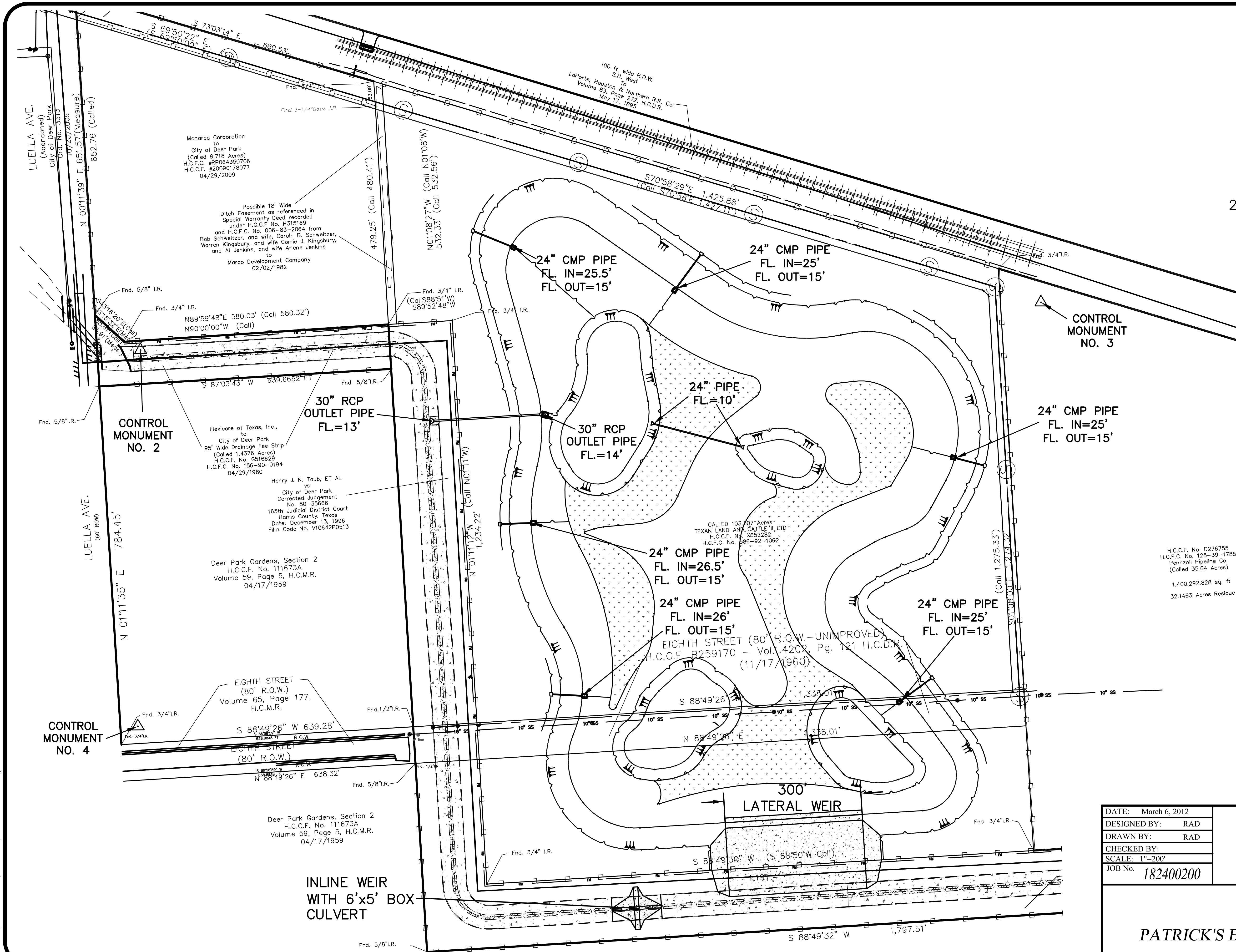

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CHECKED BY:	
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JOB No.	182400200

PATE ENGINEERS
TBPE F-002726
13333 N.W. Freeway, Suite 300 Houston, Tx. 77040
Phone: 713-462-3178

PROPOSED PLAN
FOR
PATRICK'S BAYOU DETENTION FACILITY
EXHIBIT NO. 5

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Mar 06, 2012 - 7:54am Defreitas, Robert

APPENDIX C
RESPONSE TO COMMENTS

Comments and Responses Matrix for Patrick Bayou Draft Remedial Alternatives Technology Screening

Comment No.	Section	Page	Line	Comment	Response to Comment - Proposed Revision
USEPA Comments					
1	2.1.2	7		A potential benefit of the detention basin is sediment suspended during "normal" rain events and the contribution of the suspended sediment to Monitored Natural Recovery (MNR). The detention basin also could trap suspended sediment and reduce the suspended sediment available for MNR. The net sedimentation in Patrick Bayou will need to be reevaluated after installation of the detention basin (as is noted in Section 2.2.3 Ecological Functions).	Revised the text to recognize that the effect of the detention basin will need to be evaluated after the detention basin is in operation.
2	2.1.4	9		What shear strength is required to support an articulated concrete block mat cap, or an aggregate and natural materials cap?	Added text to explain shear strength requirements for capping and differences between example cap types.
3		13		The Baseline Ecological Risk Assessment (BERA) also identified polycyclic aromatic hydrocarbons (PAHs, lead and bis(2-ethylhexyl)phthalate (BEHP) as potential contributors to sediment toxicity. Therefore, PAHs, lead and BEHP also would be indicator chemicals (ICs).	Summarized the identification of indicator chemicals consistent with previously submitted documents (BERA and BHHRA), which is that the primary IC is PCBs and that total PAHs, BEHP, and lead, which are also associated with some risk to benthic invertebrates, are secondary ICs.
4	3.1	20		Protection of benthic invertebrates due to sediment toxicity should be Preliminary Remedial Action Objective (PRAO) and should be considered to a Primary Objective.	The PRAO was added to the text as a primary objective, in conformance with the BERA, to mitigate risk to benthic invertebrates associated with PCBs and secondary COCs (PAHs, lead, and BEHP).
5	3.3.5 and 3.3.7	23 and 24		Atmospheric deposition to surface water and upstream sources are mentioned as the sources of PAHs. Other sources of PAHs such as discharge outfalls, spills and bank erosion also are plausible PAH sources. In addition, plant process equipment such as flares could serve as a PAH source.	Made no change to these sections of the text. Sections 3.3.5 and 3.3.7 are specific to atmospheric deposition to surface water and upstream sources. NPDES discharges are discussed in Section 3.3.1, spills in Section 3.3.3, and bank erosion in Section 3.3.4. Contribution from flares is addressed in Section 3.3.5 as a local source that is potentially an ultimate source of COCs through atmospheric deposition.
6	3.3.7	25		Upstream sources are mentioned as a source of polychlorinated biphenyls (PCBs). Other sources of PCBs such as discharge outfalls, spills and bank erosion also are plausible PCB sources.	Discharge outfalls are already discussed in Section 3.3.1, spills in Section 3.3.3, and bank erosion in Section 3.3.4. None of these potential sources belong in Section 3.3.7. Made no change to this section of the text.
7	4.3.2	41		"Degrade" would be more accurate descriptor than "destroy" with regard to MNR.	Suggested edit has been made.
8	Table 3-2	5		Texas Risk Reduction Program (TRRP) protective concentration limits (PCLs) may be determined to be "To Be Considered" (TBC) levels.	Updated Table 3-2 to discuss the use of the TRRP process for developing site-specific PCLs for ecological receptors and included an explanation that the tabulated PCLs, which are for protection of human health, are inappropriate for the Site, as there is no significant risk to human health at the Site.
9	Appendix A			Will work on securing some the references: a. Alcoa 2007 Grasses River Activated Carbon Pilot Study b. Reible et al. 2003 Comparison of removal and in situ management	No change required.
TCEQ Comments					
1		iv		List of Tables, please add page numbers to this list and add page numbers for each in the Tables section. Some tables are in the narrative while others are in the Tables section, page numbers in both places will make each table much easier to find.	Page numbers will be added to the List of Tables for in-text tables. Tables in the separate Tables section are so noted.
2		8 and Figure 2-4		Please add the elevation contours to the figure. Without the elevation contours it is impossible to evaluate the sub-basin boundaries. I also think that the air photo overlay would be more useful when looking at the sub-basins. While the drg with elevation contours is useful for determining boundaries in surface water flow, the air photo layer is more useful for evaluating the features that are in each sub-basin. Consider adding contours to Figure 2-4 and adding a new figure with the air photo, contours, and sub-basin boundaries.	Elevation contours based on the most recent LIDAR data were added to the figure along with an explanation of the basis for the watershed boundaries, which predate the current LIDAR data.
3	2.1.4	9		Please show the core sample locations on Figures 2-5 and 2-6.	The locations where samples were collected for the RI for analysis of constituents in bulk sediment were added to the two figures.

Comments and Responses Matrix for Patrick Bayou Draft Remedial Alternatives Technology Screening

Comment No.	Section	Page	Line	Comment	Response to Comment - Proposed Revision
4		14		Footnote – Please add TEQ to acronym list.	Defined TEQ in text and added the term and definition to acronym list.
5		21		First bullet – 'Other TDH conclusions include:" This sentence follows "As noted in the BHHRA…" As written/organized, these statements imply that TDH reviewed and concurs with the decisions in the BHHRA. TDH did their assessment years before the BHHRA was complete. Please revise this paragraph to clarify this association.	This text has been substantially revised to reflect the more recent conclusions of the USEPA-approved BHHRA and final BERA (approval pending) for the RI/FS. This information supersedes the previous TDH/ATSDR report, thus the TDH/ATSDR text has been deleted.